AESD
TECHNICAL NOTE
TN-74-04

THE FACT MODEL
VOLUME II

C. L. Baker
Ocean Data Systems, Inc.

and

C. W. Spofford
Acoustic Environmental Support Detachment

DECEMBER 1974
Reprinted July 1977
by NORDA

AESD

NUMERICAL MODELING DIVISION
NAVAL OCEAN RESEARCH
AND DEVELOPMENT ACTIVITY
NSTL STATION, MISSISSIPPI 39529

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

14

1. REPORT NUMBER: AESD-TN-74-64 — VOL-2

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): THE FACT MODEL. VOLUME II.

6

9

5. TYPE OF REPORT & PERIOD COVERED: FINAL REPORT,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s):

10

C. L. BAKER
C. W. SPOFFORD

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Acoustic Environmental Support Detachment
Office of Naval Research
Arlington, Virginia 22217

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: PE63795

11. CONTROLLING OFFICE NAME AND ADDRESS:
Numerical Modeling Division, Code 320
NORDA/Naval Oceanographic Laboratory
NSTL Station, Mississippi 39529

11

12. REPORT DATE: DEC[redacted]74

13. NUMBER OF PAGES: 167

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

12 158

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release;
distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Reprinted July 1977 by the Naval Ocean Research and Development Activity. Controlling Office updated in Item 11 above.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Transmission Loss
Ray Acoustics Model
Ray Tracing
Propagation Loss

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The FACT (Fast Asymptotic Coherent Transmission) Model is the new Navy Interim Standard Transmission Model for Ocean environments which may be treated within the context of a single sound-speed profile and a flat bottom. It is a ray-acoustics model designed for the computation of transmission loss as a function of range and frequency at fixed depth. The classical ray treatment has been augmented with higher order asymptotic

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-014-6601

408267

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

corrections in the vicinity of caustics, and the phased addition of selected paths experiencing significant, predictable coherence effects. The computer program is fully automated requiring only the specification of the environment and the essential parameters.

This report consists of two volumes, the first describing the physics and mathematics contained in the FACT Model as well as comparisons of FACT and normal-mode results. The second volume describes the program structure and flow with complete samples of input and output. Volume I has been distributed to a broad community of both technical and application-oriented users as a Maury Center Report. Volume II is intended primarily for programmers attempting to implement the model on their computers and is being distributed as an AESD Technical Note only to recipients of the FACT program. The complete program listing and punched-card deck will be provided by AESD to qualified users upon request.

Accession For
NTIS
Dist
A

AD A078539

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

4. PROGRAM STRUCTURE AND FLOW

This section is divided into four subsections:

4.1 Description of inputs

4.2 Sequence of calculations

4.3 Description of outputs

4.4 Detailed flow charts and descriptions of each of the basic programs and subroutines in the FACT package.

These sections were taken largely from the Ocean Data Systems, Inc. final report on FACT model development for AESD.*

The basic flow of the FACT model, exclusive of input and output is summarized in Figure 4-1, and is considerably expanded upon in sections 4.2 and 4.3. The complete program listing and punched-card deck are available from AESD upon request.

The objective of FACT is to estimate, by using ray-tracing techniques, the acoustic transmission loss in a single-profile, flat-bottom ocean environment, as a function of range and frequency. Additionally, if requested, FACT will produce the arrival angles (at the receiver) of individual ray paths, again as a function of range. Transmission loss (dB re 1 yard) is tabulated in a single array

---

*C. L. Baker, FACT Transmission Loss Model Development for Acoustic Environmental Support Detachment - Final Report, Ocean Data Systems, Inc., June 30, 1973 on Contract N00014-73-C-0131.

of dimension 250x6 at up to 250 equally spaced range points for each of one to six frequencies. Arrival information is written to an auxiliary (tape or disk) file as individual records containing fields for range, angle, and intensities at up to six frequencies.

As indicated in the documentation included as part of the FACT Handout, the primary component of the FACT Package is a single subroutine FACTTL, which may be incorporated into any of a number of complete programs requiring an estimation of transmission loss versus range and frequency. One example of a stand-alone program is included: TLOSS, a program which reads input parameters from cards, calls on FACTTL for losses, and prints and/or plots the results. This program is primarily useful to analysts requiring a small number of runs as part of a design program on a demand basis.

Two additional transmission loss models may be used to supplement FACT in those cases where a full FACT solution is liable to result in excessive running times. These models, SHALTL and HFCHTL, are designed specifically to approximate the results of a complete FACT solution in shallow-water transmission and half-channel transmission respectively. Subroutine HFCHTL is an integral component

of FACTTL in that the output of HFCHTL is supplemented by the output of FACTTL for the direct and bottom-reflected paths. On the other hand, in order to employ subroutine SHALTL a modification to TLOSS is required (e.g., replacing the call to FACTTL by a call to SHALTL). Care should be exercised in using both of these models as both serve only as quick-running alternatives to the normal FACT processing. Additionally, the HFCHTL model requires further care in use in that it is valid only for the specific frequencies and source/receiver combinations contained within the listing.

The documentation which follows is designed to supplement the user-oriented material presented in the FACT Handout. It is intended for computer programmers, and is primarily concerned with the overall structure and interrelation of the various components of the FACT Package. The organization of this material follows that of the FACT programs components is presented in Section 4.4.

The FACT model itself, written entirely in FORTRAN IV, is invoked by a single call to subroutine FACTTL. Core requirement, excluding input and output, but including all other FACT and system computational routines, is approximately 8,400 decimal (20,300 octal) cells on the CDC 6400/6600.

4.1 Inputs

The inputs to FACT are primarily geometrical and environmental in nature. They are:

- A sound velocity profile: the speed of sound is specified at each of up to 50 points from the surface to the bottom. Depth/velocity pairs are in feet and feet per second or meters and meters per second.
- Surface and bottom conditions: wave height in feet; FNWC bottom class.
- Source and receiver positions: depths in feet.
- Frequency information: frequencies in Hertz; coherency flags.
- Range information: number and spacing of range points in nautical miles.

4.2 Sequence of Calculation

In the following presentation, only the most significant steps in determining transmission loss are outlined; many computational steps, such as the calculation of constants and other factors essential to the calculation are covered in detail in the sections dealing with individual subroutines. Some liberties have been taken in describing the sequences of calculations, but it is essentially as follows:

- Profile correction: The profile points are corrected to take account of spherical earth geometry. Note that depths and depth indices are often used interchangeably (as appropriate) in discussing FACT.
- Axis location: The deep sound channel axis, if any, of the profile is located, and, under certain conditions the source and receiver depths are altered to allow simulation of axis-to-axis transmission.
- Profile augmentation: The source and receiver depths are inserted in the profile as explicit points, altered slightly, if necessary, to avoid equal velocities at the two depths.
- Source selection: For the remainder of the FACT calculations, the source and receiver depths are selected from the two depths of interest by assigning the depth with the lesser sound velocity as the source depth -- the starting point for the ray tracing process. The index of this point in the profile, K1, is used hereafter to designate the source (or source depth); the other index, K2, is used to designate the receiver or receiver depth. (Care is taken to distinguish the "true" source from the ray-tracing source where the distinction is important.)

- Geometry factors: A number of flags are set (at various points throughout the program) to indicate various geometrical relationships between source and receiver.
- Low-frequency effects: The WKB* phase factors for low frequency cutoff are calculated.
- Ray selection: The angles of the rays to be traced from K1 to K2 are selected, grouped into one or more families. The selection is based on the velocity profile, source, and receiver depths. Rays are chosen so that within each family, an analytical fit of Range versus Angle can be made, thus smoothing and retaining legitimate caustics while removing false caustics; the functional form of the fit will vary with family type. If the profile and associated source and receiver depths lead either to more than 20 families or 100 rays, processing is terminated and the transmission loss array is returned with zero values for all entries.
- Ray tracing notes: Because the environment is single profile, flat bottom, any ray which is traced exhibits a periodicity over the range of interest and is actually traced for only a single such cycle.

* Wentzel-Kramers-Brillouin approximation - see L. M. Brekhovskikh, Waves in Layered Media, Academic Press, New York, 1960b, pp 452-3.

Within a single period, each ray angle selected may represent one, two, or four paths (arrivals) from source to receiver, per period, depending upon the geometry involved: the source angle may be positive, negative, or both, and may either be reflected or refracted at the receiver, or may cross and re-cross the receiver depths. Each arrival is assigned a number, termed the arrival order, indicating the number of deep cycles which the ray has undergone; arrival order corresponds to the direct path. The ordering of arrival ranges within a single period or cycle of a ray, and the assignment of these ranges (plus multiples of the period) to individual arrival orders is determined and controlled by a number of flags and indices which are detailed elsewhere.

. Path combinations: Depending upon the geometries involved, two or four paths from the source to the receiver may be combined into a single path of doubled or quadrupled intensity. This may happen for instance, if the source is so close to the surface that the downgoing ray and the surface-reflected upgoing ray are essentially parallel and arrive at the receiver at essentially identical angles. A similar geometry may apply at the receiver, or at

both the source and receiver. The processing of such combined rays is controlled by several flags indicating the simplified situation.

- Family processing: Each family, in turn, is processed to determine its contributions to the total intensity arising from the source, and equivalently, overall transmission loss. At the same time, individual arrival angles and intensities are written to a separate file for later processing. This loop on families is the major processing loop in FACT- Within each family, the zero-order or direct path is processed first. This is followed by a loop in which subsequent orders 1, 2, 3,... are processed in turn. There is no fixed limit on the number of orders which FACT may be required to process; this loop is terminated only when significant intensity no longer is being contributed by any path within the family at the ranges of interest.
- Half-channel note: When a half-channel case has been flagged on input, only the direct and bottom and surface-reflected arrivals are processed as outlined above. In these cases, the non-direct path, non-bottom and surface reflected contribution to intensities are approximated and added by a separate half-channel model.

- Final processing: When all families have been processed, surface-duct contributions, if present, are added to those intensities already calculated, and then converted to transmission losses (re one yard).

Processing of an arrival order of a family of rays consists of the following steps:

- The arrival ranges for each of the (one to four) paths with this order are calculated.
- For each path, the coefficients and parameters required to express range as a function of ray angle are calculated. Any one of four possible functional forms is used according to family characteristics.
- If the range intervals for all four paths exceed the maximum range of interest, processing of arrival orders for the family is terminated.
- Subroutine INSTOR (or CUSP if applicable) is called to calculate and add the intensity arising from each (smoothed and fitted) path to the transmission loss array at each range point for each frequency.
- If the intensities from all four paths drop below a specified minimum value, processing of arrival orders for the family is terminated.

Processing of one path of an arrival order by INSTOR or CUSP consists of the following steps:

- The type of fit of range versus ray angle is examined to determine whether or not a caustic exists, and to find the minimum and maximum ranges at which contributions to total intensity are made.
- If this range interval is beyond the range of interest, processing of the path is terminated.
- At each applicable range point, the number of arrivals (rays) is calculated: zero indicates the shadow zone of a caustic, one or two indicates an illuminated region.
- The intensity contribution from each ray is added to the transmission loss array for each frequency at the range being processed. The intensity is computed as an analytic function of range, frequency, and the values of ray angle and the derivations of range with ray angle at this range; the latter are obtained by examination of the range versus ray angle fit.
- The calculated intensities are modified, if required by factors reflecting coherent, semi-coherent, or incoherent path addition, shadow-zone fall-off, low-frequency cutoff effects, and bottom-bounce losses as applicable.
- If flagged, range, arrival angle, and intensity information is written to an external file.

- When all range points have been processed, a flag is set to indicate if the minimum range of the path has exceeded the range of interest, or if the contribution to intensity has dropped below a specified minimum value.

4.3 Outputs

The primary output from subroutine FACTTL is an array, TL, of dimension 250x6, giving transmission loss (in dB re 1 yard) at each of the range points and frequencies specified as input parameters. If the ray selection process results either in too many rays (> 100) or too many families (> 20), a two-line message will be printed indicating this condition, and the TL array will contain zeros at the specified ranges and frequencies.

If, in addition, arrival information is desired, the input parameter IAR should be set indicating the FORTRAN unit to which arrival records should be written. The format of these records is detailed in the description of subroutine INSTOR.

The output file is never positioned nor are any file marks written; these functions are delegated to the calling program.

Optional debugging output is also available via an input parameter; care should be taken in setting this flag, as the potential exists for many hundreds of pages of output from a single run.

4.4 Components of the FACT Package

This section consists of a description of each of the components of the FACT Package -- the driver programs, the main computational routine, and auxiliary subroutines and functions. For each of these, the following material is included:

- A brief description of the function of the component in the Model.
- Equations used by the component when these are not immediately evident from the function of the component and/or the program listing.
- Parametric and common input and output variables.
- Flow charts, expressed in physical terms to the greatest extent possible, for the major programs and routines of the Model.
- Additional material, as applicable, to present the details of the program logic not included in the flow charts for the routine.

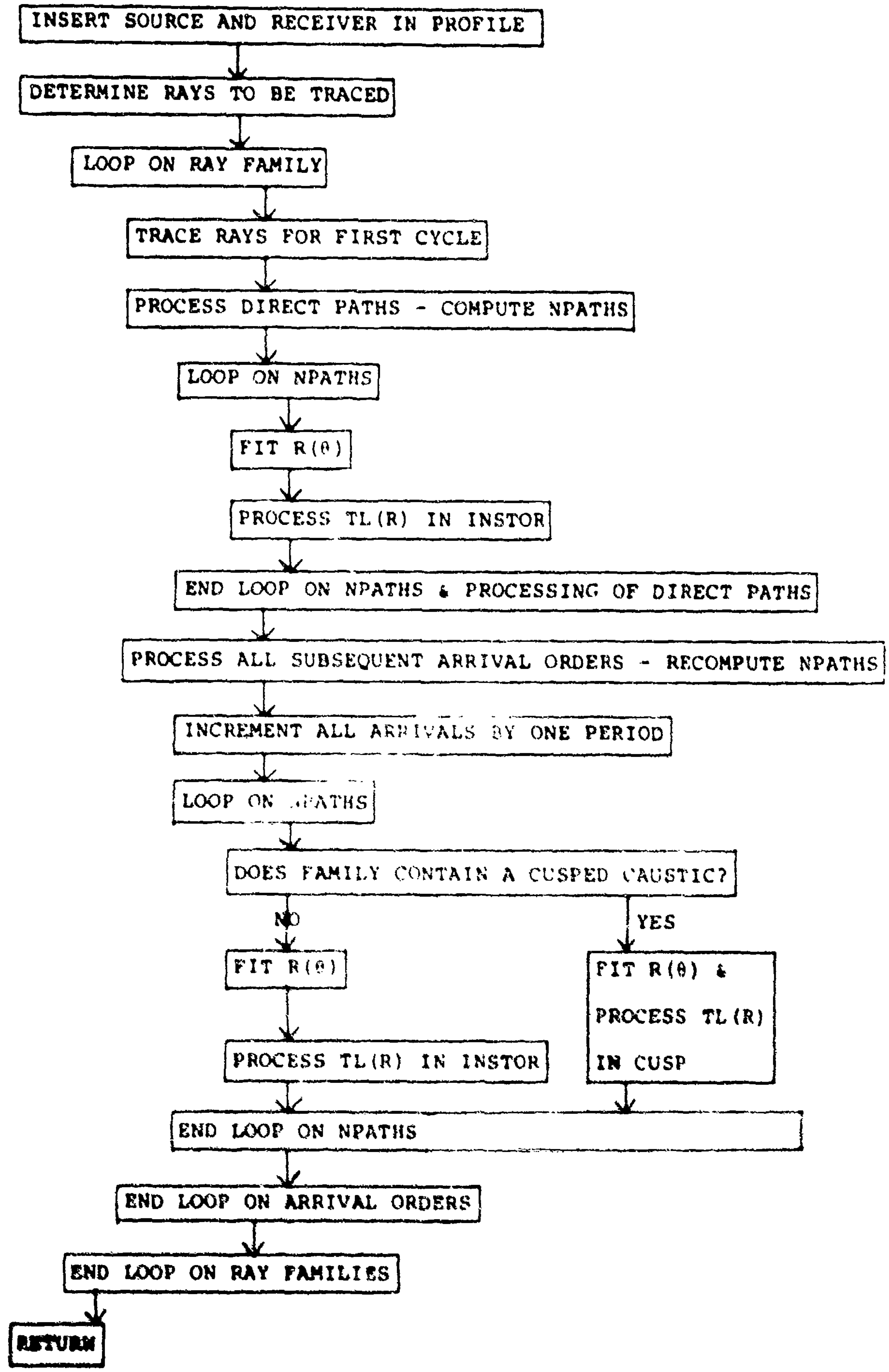


Figure 4-1. OVERVIEW OF PROGRAM FLOW IN FACTEL

PROGRAM TLOSS

TLOSS is the driver which reads card inputs, invokes FACTL to compute transmission loss (and arrival structure) versus range and frequency, and prints and/or plots the results.

CARD INPUTS

The card input formats and sequence are detailed in the FACT Handout, pages 5-9 through 12. See also subroutine RDPROF, page 4-17.

PRINTED OUTPUTS

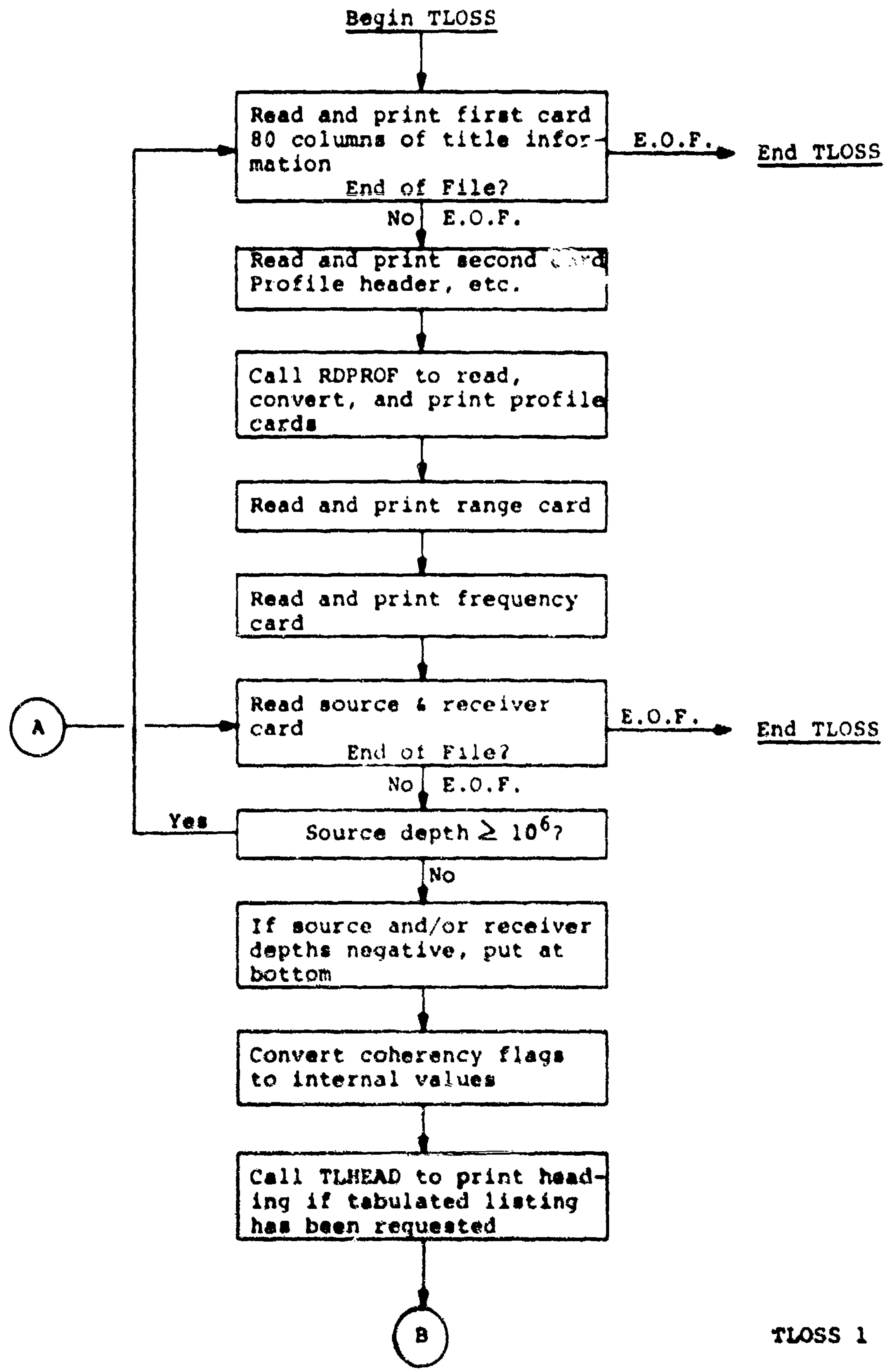
The formats for tabulated and plotted printer outputs are detailed in the FACT Handout, pages 5-14 through 33. See also subroutine TLHEAD, and PLOTTL, pages 4-19 and 20. TLOSS also prints the data on the input cards as they are read.

COMMON USAGE

None

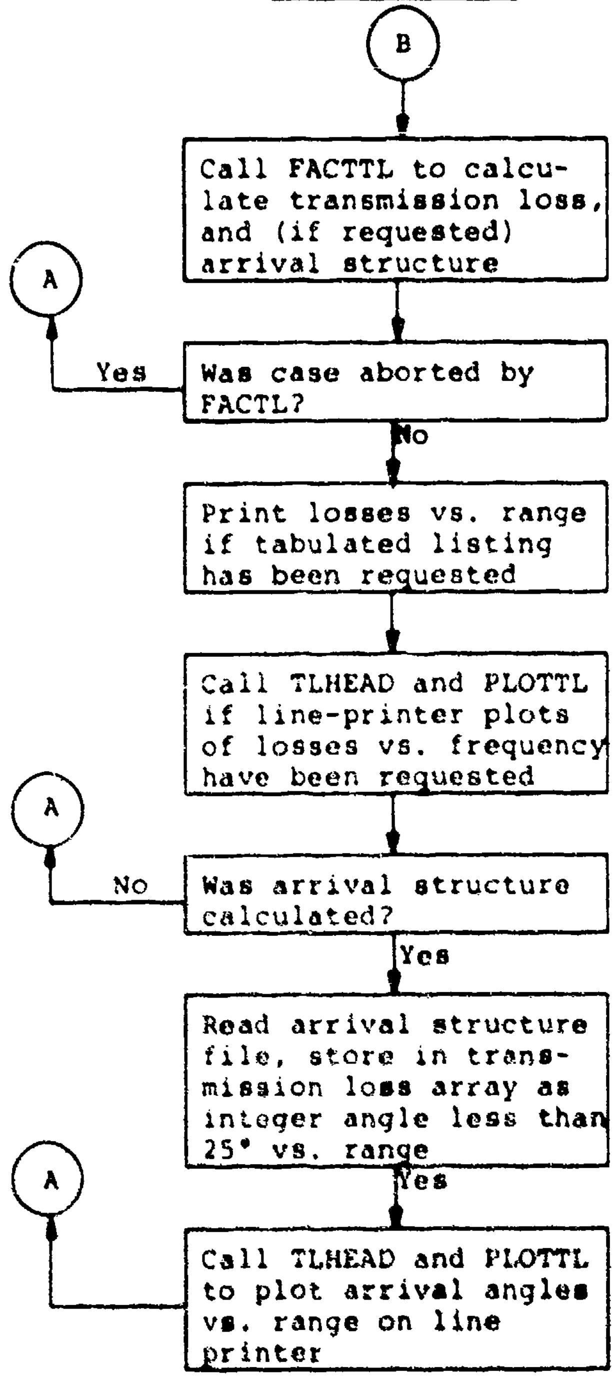
NOTE

A complete FORTRAN listing of TLOSS is included in the portion of the FACT Handout included in this report, pages 5-43 through 47.


Begin TLOSS
Read and print first card 80 columns of title information
End of File?
E.O.F.
End TLOSS
No E.O.F.
Read and print second
Profile header, etc.
Call RDPROF to read, convert, and print profile cards
Read and print range card
Read and print frequency card
A
Read source & receiver card
End of File?
E.O.F.
End TLOSS
No E.O.F.
Yes
Source depth ≥ 10⁶?
No
If source and/or receiver depths negative, put at bottom
Convert coherency flags to internal values
Call TLHEAD to print heading if tabulated listing has been requested
B

TLOSS 1

Continue TLOSS



SUBROUTINE RDPROF

RDPROF is called from TLOSS to read profile data from cards, and convert, if necessary, to FACT units. Card formats are detailed in the FACT Handout. Input data is printed as it is read; see pages 5-14, 5-23 and 24, and 5-33.

PARAMETER INPUT

N : No. of Profile Points

CARD INPUTS

A) N Positive:

Z Profile Depths (4/Card), meters or feet

C Profile Velocities (4/Card), mtrs/sec or ft/sec

B) N Negative:

D Profile Depths, meters

T Profile Temperatures, degrees Centigrade

S Profile Salinities, parts/thousand

PRINTED OUTPUTS

The data read from cards is printed along with the results of any conversions performed. One of three applicable formats is used:

1) Depths in feet and velocities in feet per second.
2) Depths in meters and velocities in meters per second, plus depths in feet and velocities in feet per second.
3) Depths in meters, temperatures in degrees Centigrade,

salinities in parts per thousand, plus depths and and velocities as in 2).

PARAMETER OUTPUTS

Z Array (50) of Profile Depths, feet

C Array (50) of Profile Velocities, ft/sec

COMMON STORAGE

None

SUBROUTINE TLHEAD

TLHEAD is called from TLOSS for the purpose of printing any of three different heading formats; these are detailed in the FACT Handout.

PARAMETER INPUTS

TITLE	80 Character Title (8 words, 10 char/word)
S	Source Depth, feet
R	Receiver Depth, feet
IF	Array (6) of Frequencies, Hz
JC	Array (6) of Coherency Flags, (0,1 or 2)
IX	Array (6) of Characters to be Used for Plotting
NF	No. of Frequencies
ITYP	Heading Type, 0,1,2

PRINTED OUTPUTS

A) ITYP = 0:

Page Heading for Tabular Transmission Loss vs. Range

B) ITYP = 1:

Page Heading for Plot of Transmission Loss vs. Range

C) ITYP = 2:

Page Heading for Plot of Arrival Angle vs. Range

COMMON STORAGE

None

SUBROUTINE PLOTTL

PLOTTL is called by FACTTL for the purpose of plotting, using the line printer, either transmission loss versus range or arrival angle versus range. The plot format, examples of which appear in the FACT Handout, consists of an array of printer positions 121 columns wide and 51 columns high, augmented by horizontal and vertical scale information. Input is taken from an array, TL, of dimension 250 (range points) by 6 (frequencies or angles). Up to 250 range points and up to 6 frequencies or angles may be plotted. Either a separate (input) or a single (default) plotting character may be used for each frequency or angle; this is controlled by flag IX. Alternate range points only are plotted when the number of range points exceeds 120. MNDB is the minimum value of the plot: If greater than zero, the abscissa values increase downward from MNDB to MNDB + 50; if less than zero, the abscissa values decrease downward from ABS(MNDB) to ABS(MNDS) - 50. The units of the incremental range, DR, are arbitrary, but such that the maximum range is 9999.9 (nm) or less.

PARAMETER INPUTS

NR	Number of range points, ≤ 250
DR	Incremental range, nautical miles
NF	Number of frequencies, ≤ 6
IX	Array (6) of plotting characters; or zero
MNDB	Minimum value of output plot, dB or degrees
TL	Array (250,6) of values to be plotted, dB or degrees

PRINTED OUTPUT

Line printer plot of the values in TL as a function of range, with up to six plotted values at each of up to 120 range points.

COMMON STORAGE

None

SUBROUTINE FACTTL

FACTTL is the subroutine which is to be invoked in order to calculate transmission loss (and arrival angle) vs. range. All input and output is directed by the values of the parameters of the call to FACTTL; the common storage of FACT and its subroutines must be kept separate from that of any calling routine. A condensed description of the major processing done by FACTTL is found on pages 5-5 through 7.

PARAMETER INPUTS

YS	Source depth, feet
YR	Receiver depth, feet
FREQB	Array (6) of frequencies, Hz
IC	Array (6) of coherency flags; 0,1 or 2
WHF	Wave height, feet
IB	FNWC bottom type, 1-9
NPTSPP	No. of points in sound velocity profile, ≤ 50
IL	Index of surface layer in profile, ≤ 50
YPP	Array (50) of profile depths, feet
CPP	Array (50) of profile velocities, feet per second
NR	No. of range points, ≤ 250
DR	Incremental range, feet
IARVTP	File unit for arrival output if ≠ 0
IP	Debugging print flag, 0 or 1

PARAMETER OUTPUTS

TL	Array (250,6) of transmission loss vs. range and frequency, dB

FILE OUTPUT

Unit IARVTP	One record for each arrival angle at each range point, including path loss vs. frequency. (See INSTOR for format, page 4-79)

COMMON VALUES CALCULATED

/RANGEL/	NRANGE	No. of range points (≤ 250)
	NFREQ	No. of frequencies (≤ 6)
	IFQMIN	Index of lowest frequency ≤ 6
	FREQ	Array (6) of (radian frequencies)**-1/3
	FREQK	Array (6) of frequencies in KHz
	RANGE	Array 2[illegible] of range values, feet
/FLAGS/	IGTYP	Type of family being processed 1-4
	THMIN	Angle giving minimum range in fit, Rad
	THMAX	Angle giving maximum range in fit, Rad
	CONST	Const*(Receiver Velocity)**1/3
	C1C2	Ratio of source depth velocity/ receiver depth velocity
	CBC2	Ratio of bottom velocity/receiver depth velocity
	ICOH	Flag to indicate combination of arrivals, 0-3
	IRSR	Flag to indicate surface reflection
	NBOT	No. of bottom reflections

FACTTL (Cont'd)

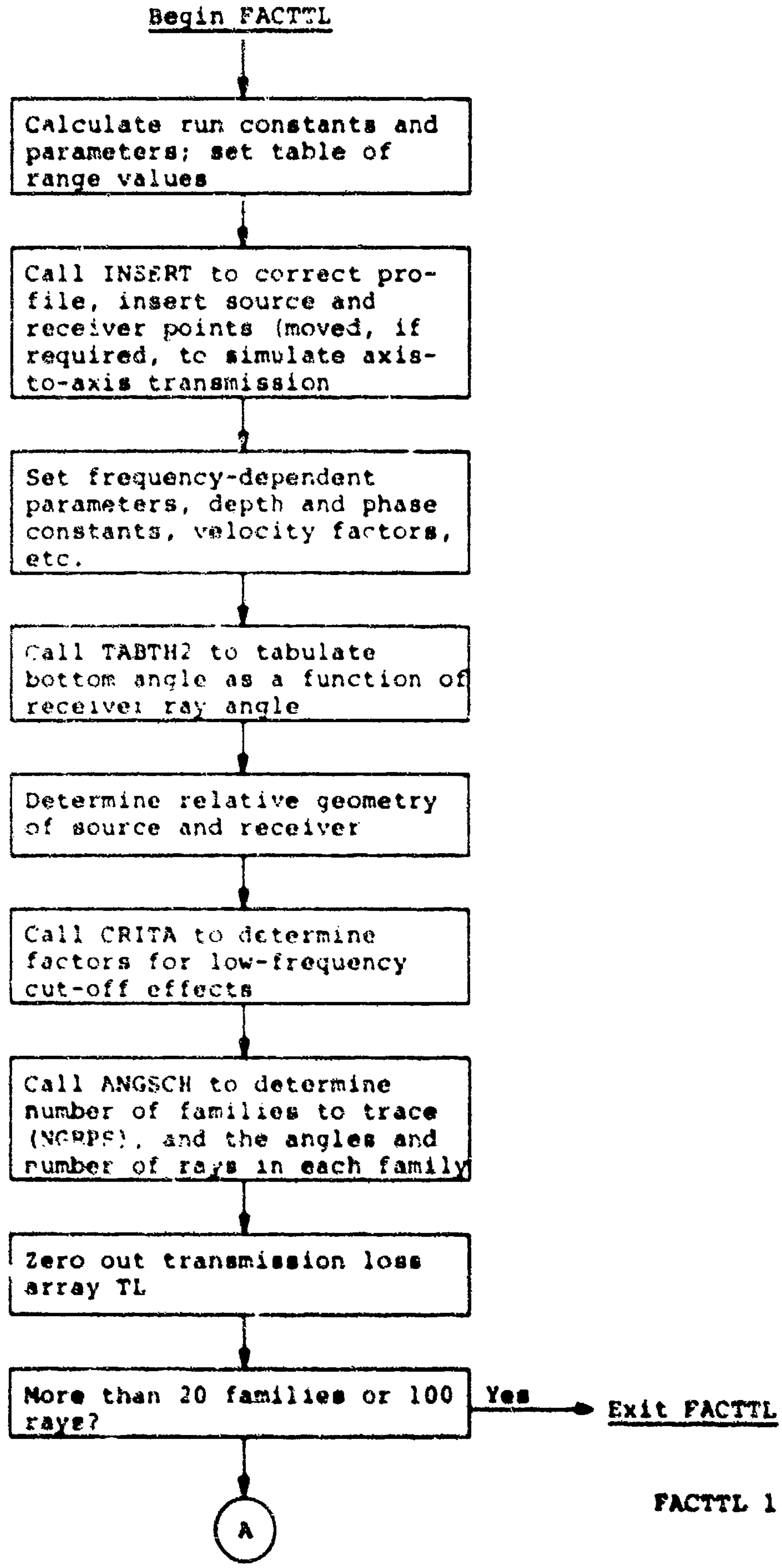
	IBTYP	FNWC bottom type
	IFLAG	Array (6) of coherency flags
	DK	Array (2,6) of semi-coherent phase factors
/RAYZER/	IREFRZ	Flag indicating grazing family
	THETMB	Critical angle for bottom type, radians
	THBINC	Incremental angle for bottom rays, radians
/INIT/	AK	Vertex velocity of ray to be traced
	SINTHO	Sine of initial angle of ray to be traced
	IML	Index of mixing layer in input profile
/INPUTS/	IRAY	Number of rays (in TH) in family being processed (≤ 100)
	KP	Index (in R) of arrival being processed (1-4)
	NP	Index of path being processed (1-4)
	NORDER	Arrival order being processed
	NG	Index of group (family) being processed (≤ 20)
	IPAR	Flag for type of family being processed (1 or 2)
	R	Array (100,4) of arrival ranges vs. angle and arrival, ft
	TH	Array (100) of ray angles in family being processed, rad
/FITS/	THF	Array (3) of angles of fit of R vs. θ
	A	Array (5) of coefficients of fit

FACTTL (Cont'd

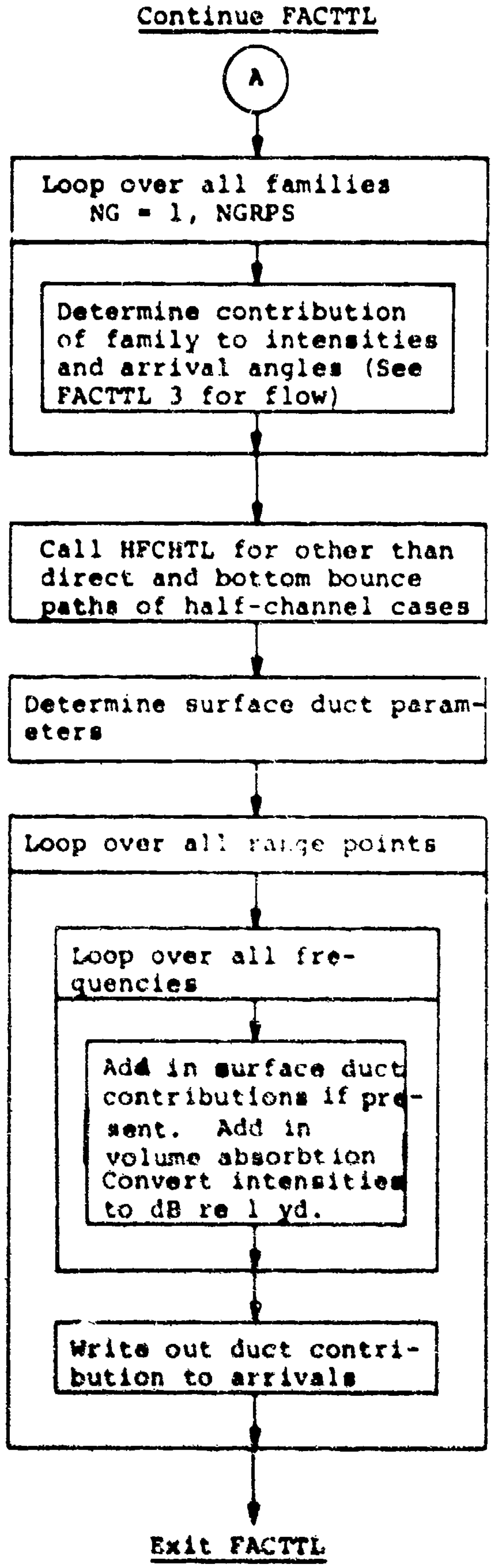
	XMIN	Ordinate value for min value of fit
	XMAX	Ordinate value for max value of fit
	RMIN	Minimum value of range in fit
	RMAX	Maximum value of range in fit
	RANMIN	Minimum range value to be fit
/CUSPCM/	CCUSP	Velocity at cusp depth, ft/sec
/AUTCOH/	FNMIN	Min no. of range pts/surf image cycle = 8/3
	FNMAX	Max no. of range pts/surf image cycle = 6
	FNXI	Reciprocal of FNMAX-FNMIN
	FNCYC	Array (2,6) of cycles of phase difference

NOTE

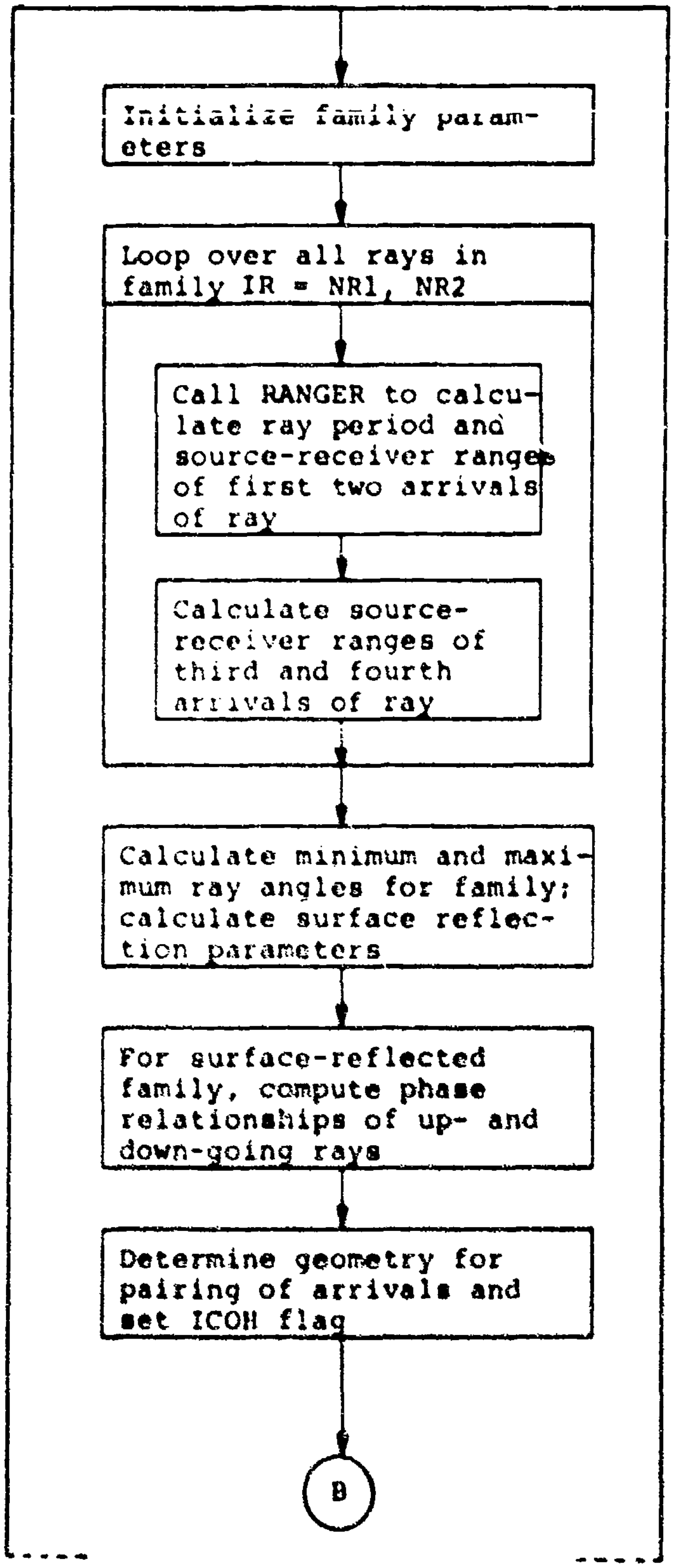
Following the flow charts for FACTTL, additional pages are presented which elaborate on the geometry of the ray paths which are used in the FACT transmission loss calculation, and the values of flags and indices required to sequence the corresponding path ranges as a function of family, arrival order and path index.


Begin FACTTL
Calculate run constants and parameters; set table of range values
Call INSERT to correct profile, insert source and receiver points (moved, if required, to simulate axis-to-axis transmission
Set frequency-dependent parameters, depth and phase constants, velocity factors, etc.
Call TABTH2 to tabulate bottom angle as a function of receiver ray angle
Determine relative geometry of source and receiver
Call CRITA to determine factors for low-frequency cut-off effects
Call ANGSCH to determine number of families to trace (NGRPS), and the angles and number of rays in each family
Zero out transmission loss array TL
More than 20 families or 100 rays?
Yes
Exit FACTTL
A

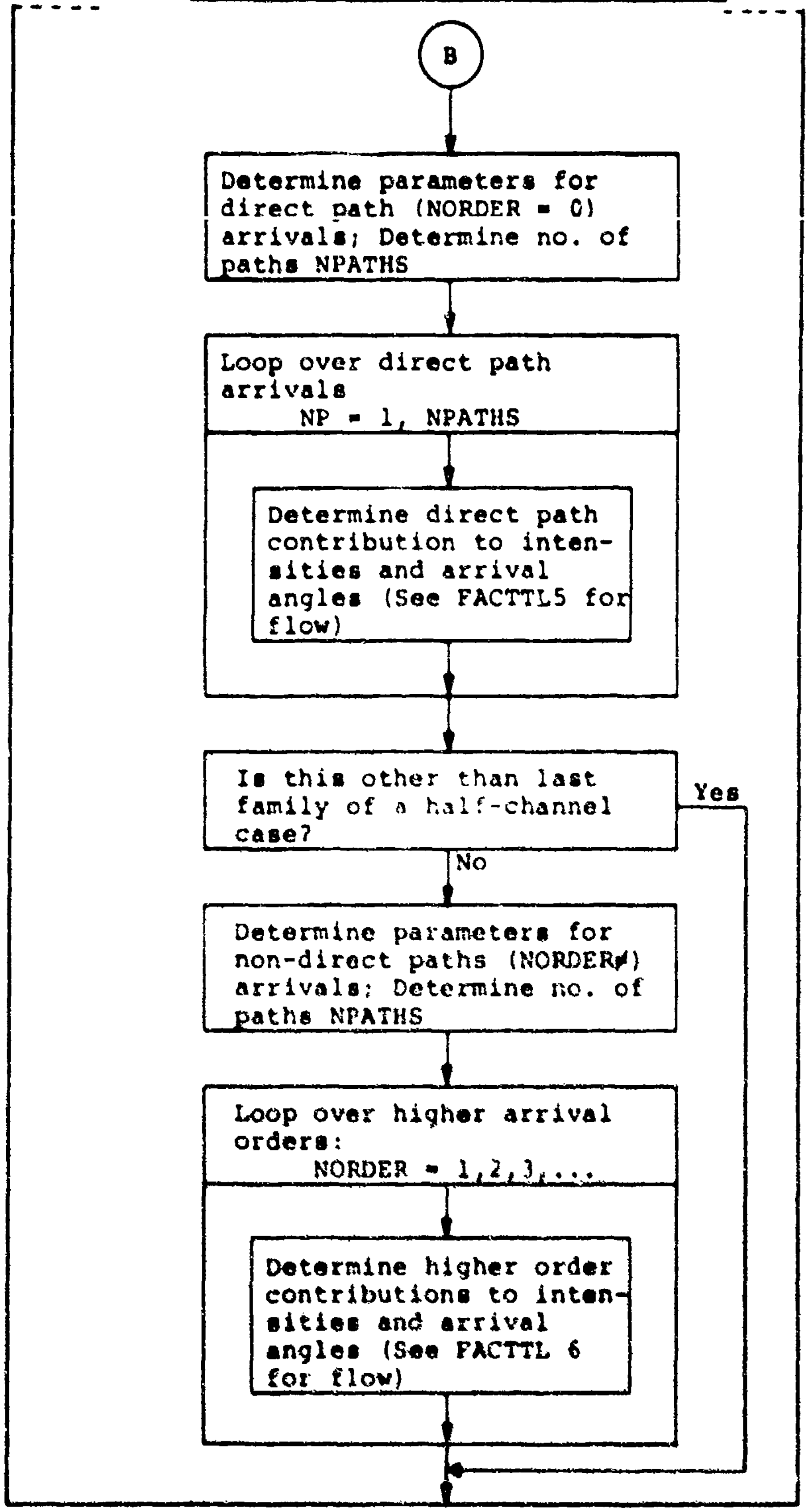
FACTTL 1


Continue FACTTL
A
Loop over all families NG = 1, NGRPS
Determine contribution of family to intensities and arrival angles (See FACTTL 3 for flow)
Call HFCHTL for other than direct and bottom bounce paths of half-channel cases
Determine surface duct parameters
Loop over all range points
Loop over all frequencies
Add in surface duct contributions if present. Add in volume absorbtion Convert intensities to dB re 1 yd.
Write out duct contribution to arrivals
Exit FACTTL

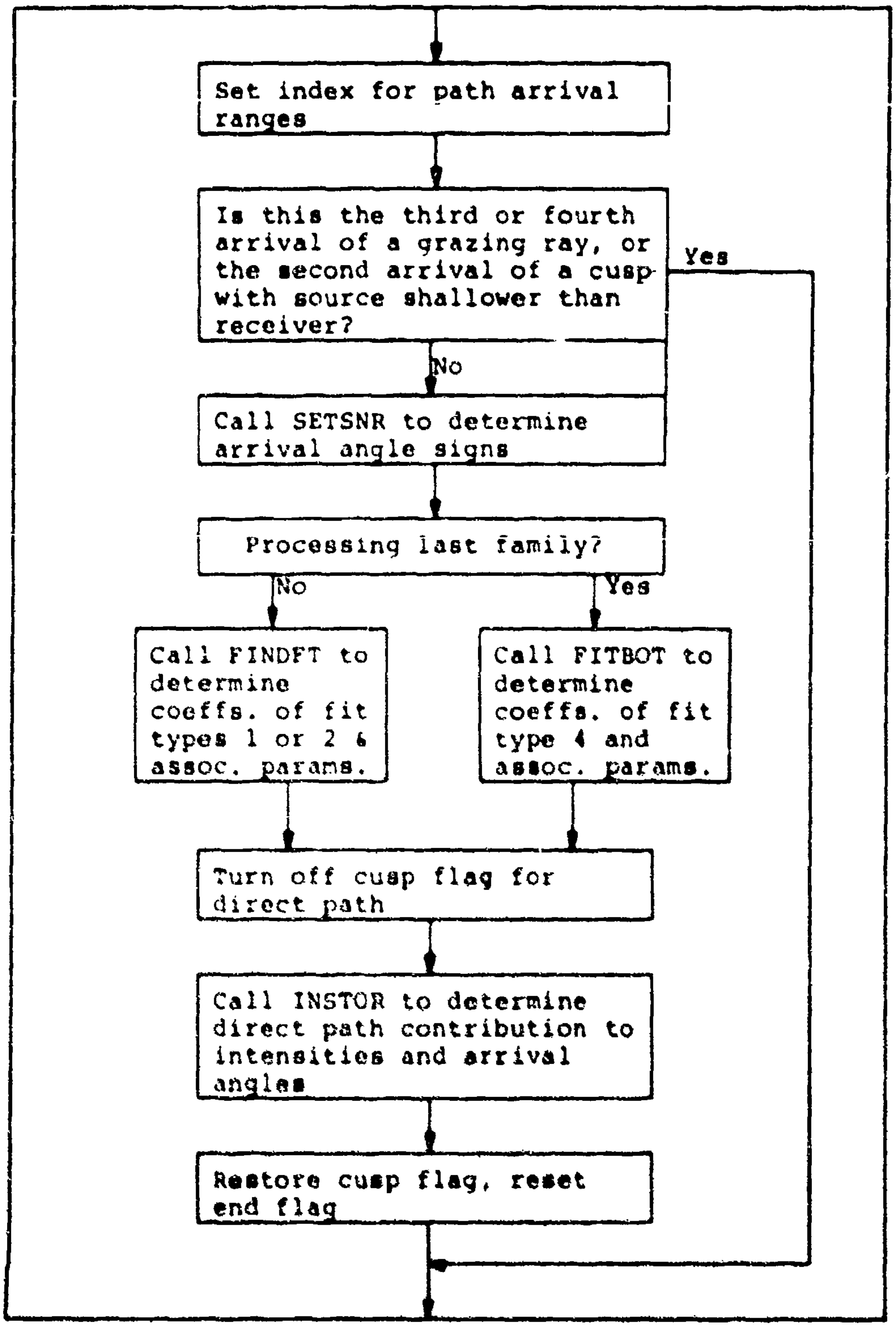
FACTTL - Loop on Families



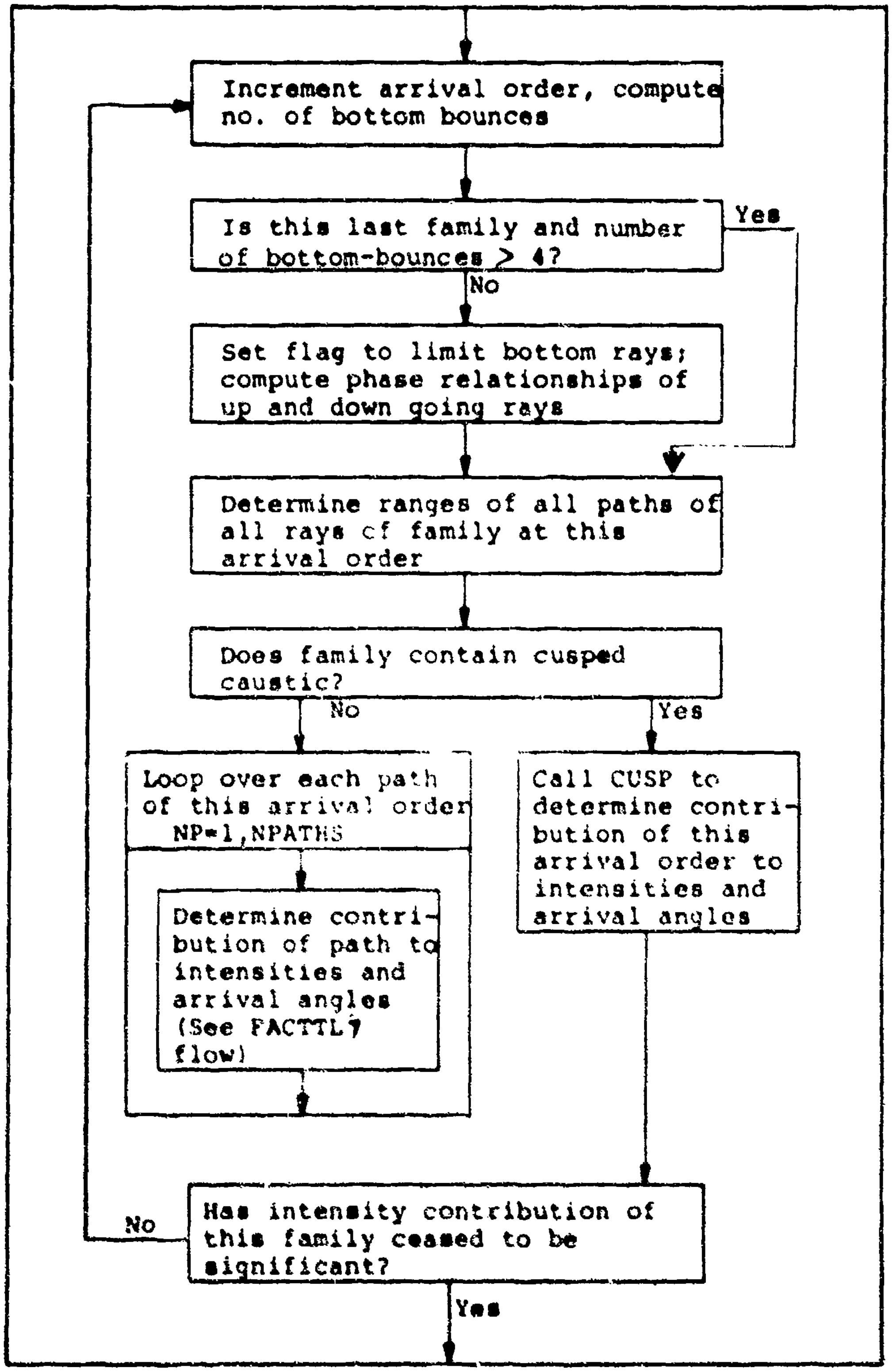
Continue FACTTL - Loop on Families



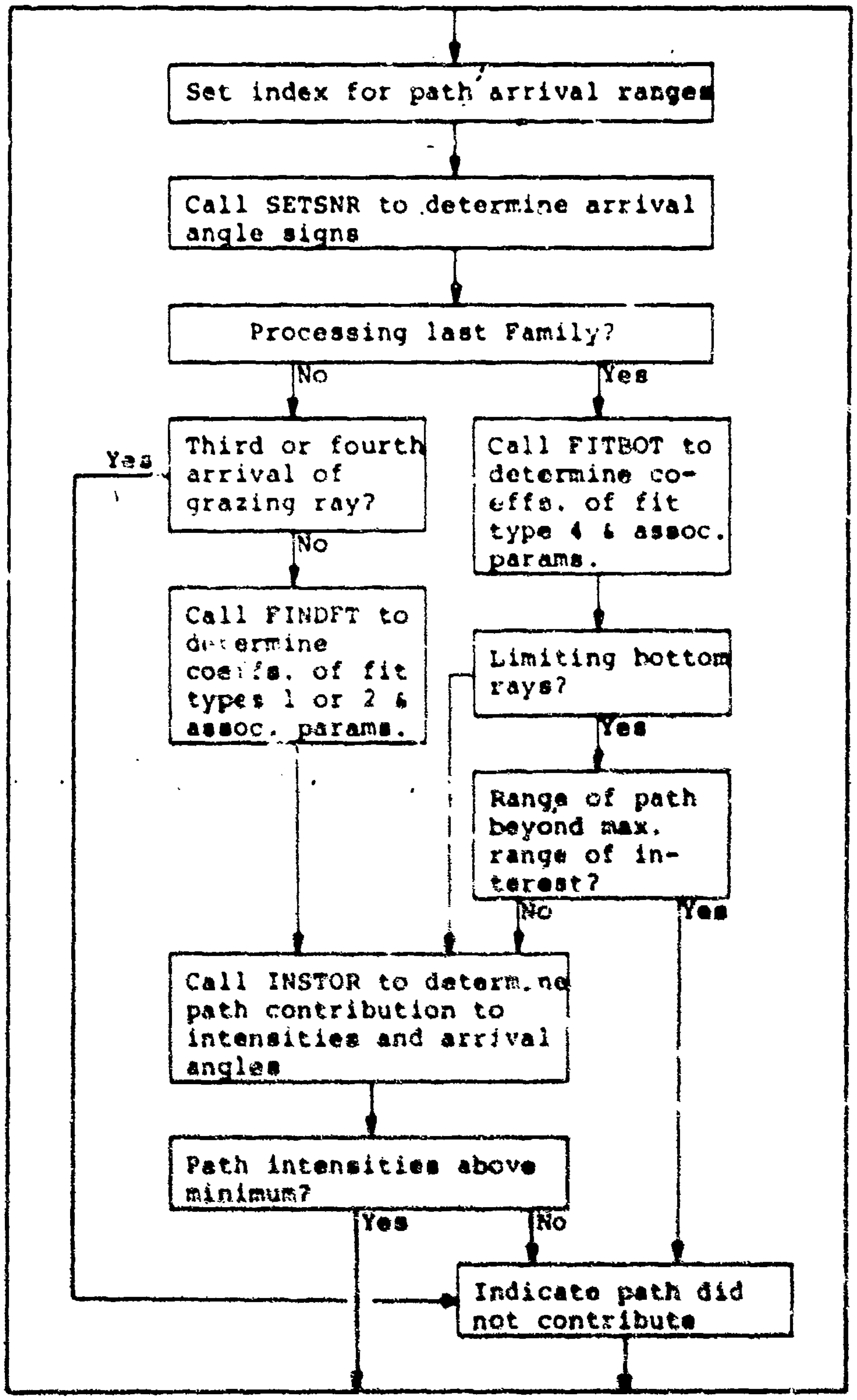
FACTTL - Loop on direct path arrivals



FACTTL - Loop on higher arrival orders



FACTTL - Loop on paths of higher arrival orders



RECEIVER DEPTH-K2	SOURCE DEPTH - K1: AT SURFACE	IN BETWEEN	ON BOTTOM
AT SURFACE	--	4	7
IN BETWEEN	2	1	3
ON BOTTOM	6	5	--

FACTTL - Setting Of Geometry Indicator KFLAG

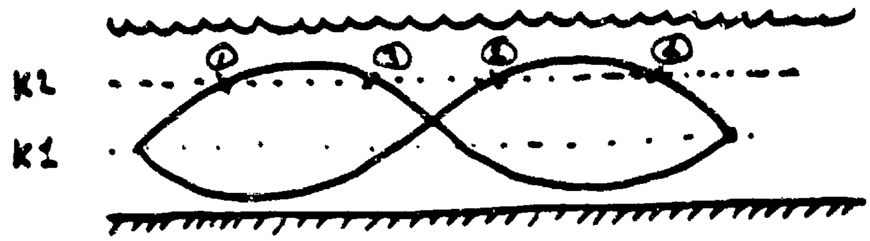
		NORDER = 0					NORDER = 1, 2, 3...								
PATH GEOMETRY				IPF (NP)		TEMP		IPF (NP)				IONE (NP)			
XFLAG		ICOH	NPATHS	1	2	ICOH	NPATHS	1	2	3	4	1	2	3	4
1:	K1 DEEPER THAN K2	0	2	1	3	0	4	2	4	1	3	1	1	0	0
		2	1	1	-	2	2	2	1	-	-	1	0	-	-
		3	1	1	-	2	1	2	-	-	-	1	-	-	-
1:	K2 DEEPER THAN K1	0	2	2	1	0	4	4	3	2	1	1	1	0	0
		1	1	2	-	1	2	4	2	-	-	1	0	-	-
		3	1	2	-	1	1	4	-	-	-	1	-	-	-
2:	K1 SURFACE	0	1	1	-	0	2	3	1	-	-	1	0	-	-
	K2 BELOW	2	1	1	-	0	1	3	-	-	-	1	-	-	-
3:	K1 BOTTOM	0	2	1	3	0	2	1	3	-	-	0	0	-	-
	K2 ABOVE	2	1	1	-	2	1	1	-	-	-	0	-	-	-
4:	K2 SURFACE	0	1	1	-	0	2	2	1	-	-	1	0	-	-
	K1 BELOW	1	1	1	-	0	1	2	-	-	-	1	-	-	-
5:	K2 BOTTOM	0	2	2	1	0	2	2	1	-	-	0	0	-	-
	K1 ABOVE	1	1	2	-	1	1	2	-	-	-	0	-	-	-
6:	K1 SURFACE K2 BOTTOM	0	1	1	-	0	1	1	-	-	-	0	-	-	-
7:	K1 BOTTOM K2 SURFACE	0	1	1	-	0	1	1	-	-	-	0	-	-	-

FACTTL - Indices for Determination of Arrival Ranges

1, 2 etc. refer to path subscript values in R (angle,path) array

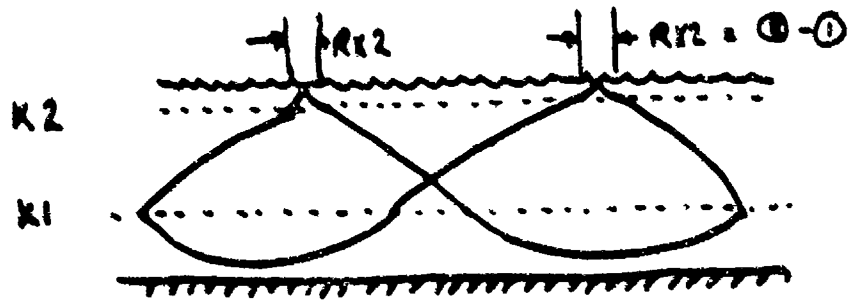
KFLAG = 1

(K1 deeper than K2)

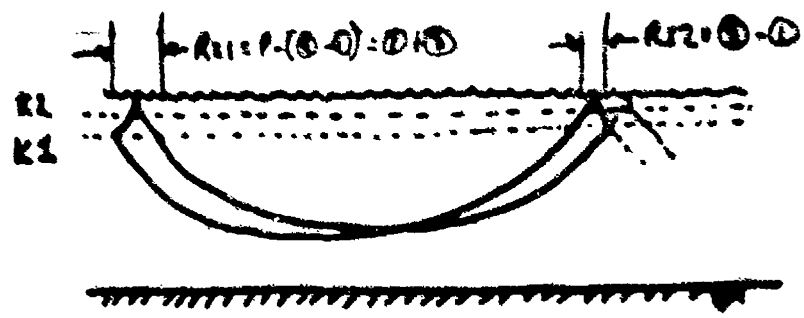


ICOH = 0

(ICOH = 1 NOT POSSIBLE)



ICOH = 2

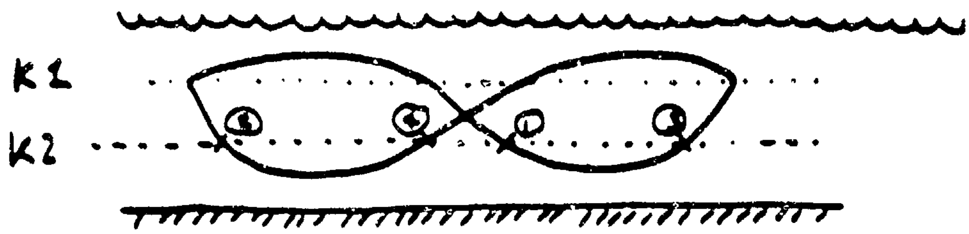


ICOH = 3

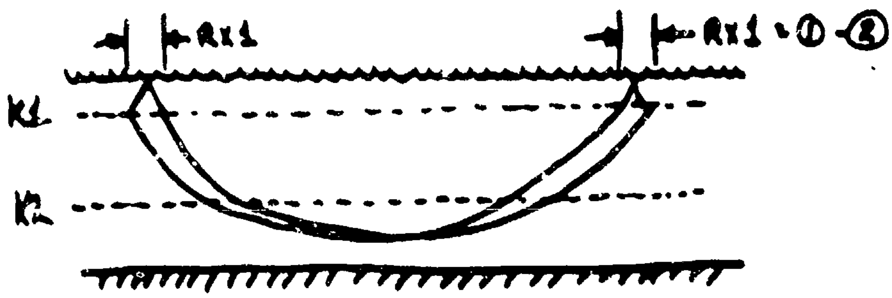
FACTTL - Coheren e Geometry for Combining Ray Paths
1 of 8

KFLAG = 1

(K2 deeper than K1)

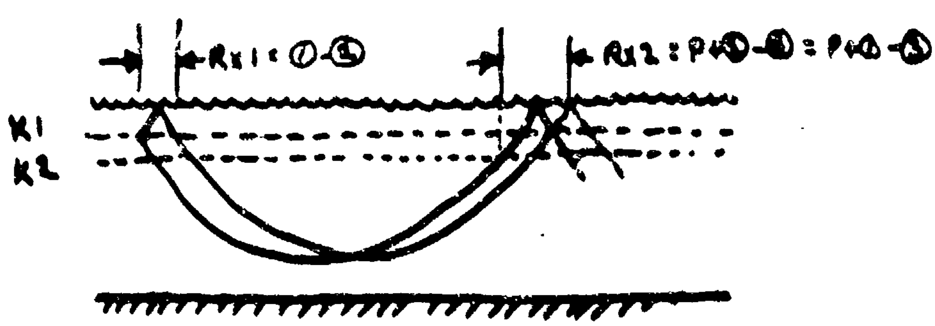


ICOH = 0



ICOH = 1

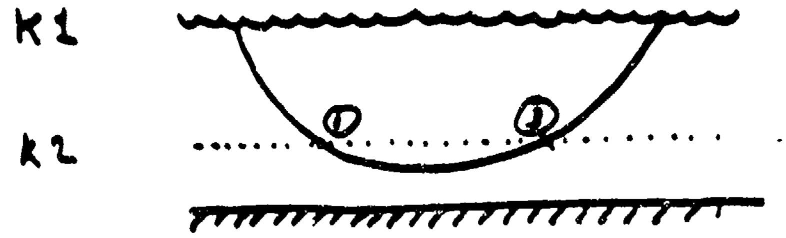
(ICOH = 2 NOT POSSIBLE)



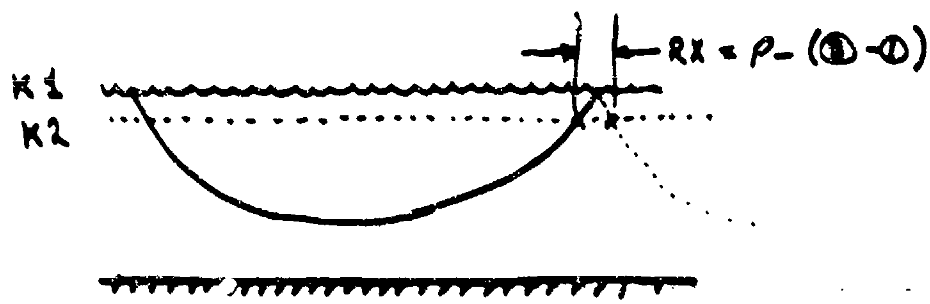
ICOH = 3

FACTTL - Coherence Geometry for Combining Ray Paths
2 of 8

KFLAG = 2



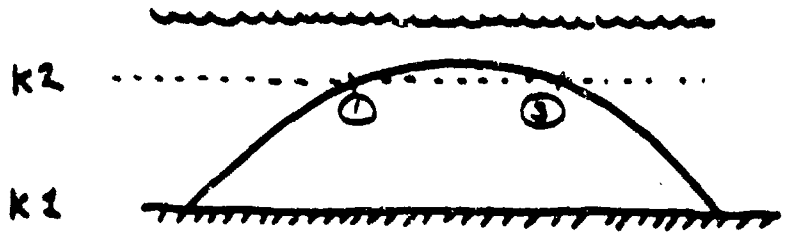
ICOH = 0



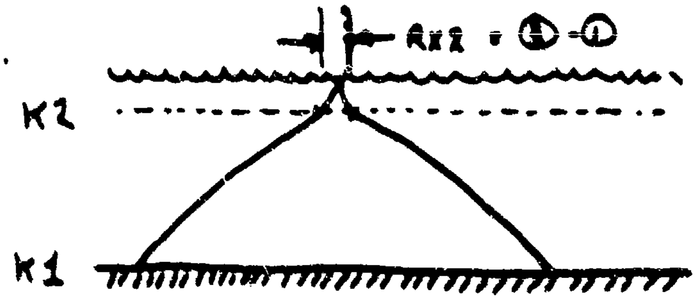
ICOH = 2

FACTTL - Coherence Geometry for Combining Ray Paths
3 of 8

KFLAG = 3



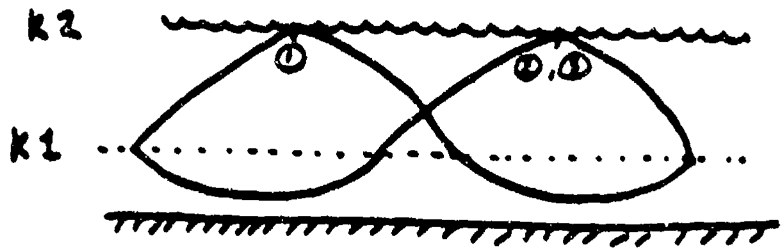
ICOH = 0



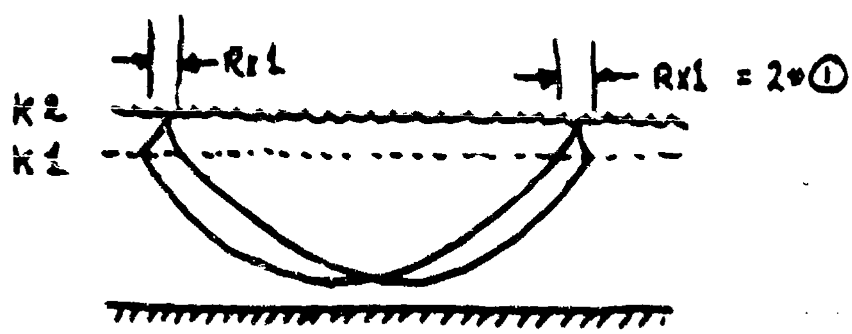
ICOH = 2

FACTTL - Coherence Geometry for Combining Ray Paths
4 of 8

KFLAG = 4



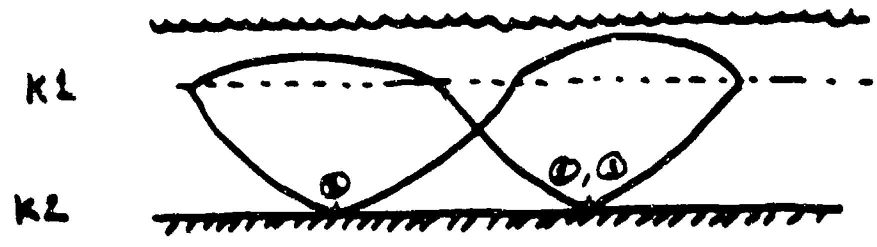
ICOH = 0



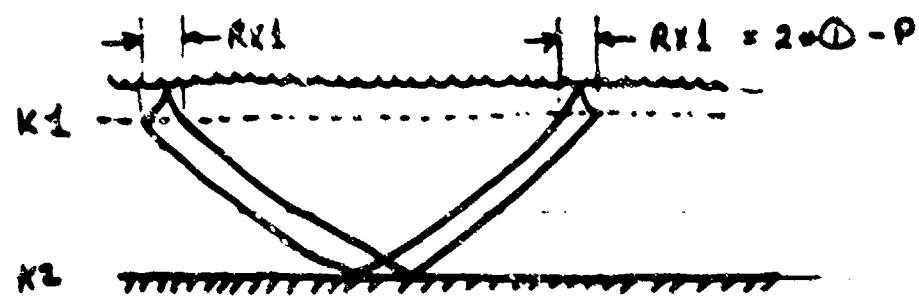
ICOH = 1

FACTTL - Coherence Geometry for Combining Ray Paths
5 of 8

KFLAG = 5



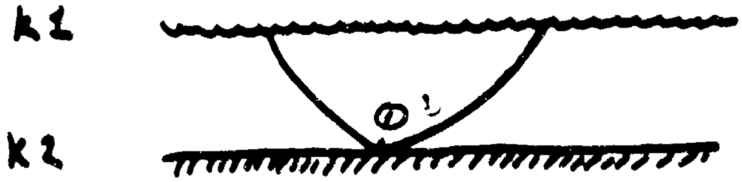
ICOH = 0



ICOH = 1

FACTTL - Coherence Geometry for Combining Ray Paths
6 of 8

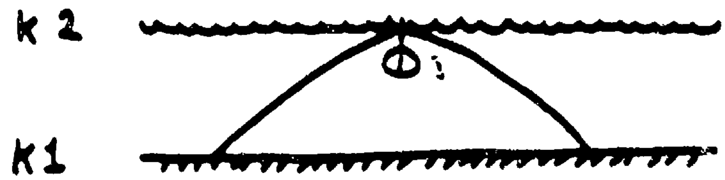
KFLAG = 6



ICOH = 0

FACTTL - Coherence Geometry for Combining Ray Paths
7 of 8

KFLAG = 7

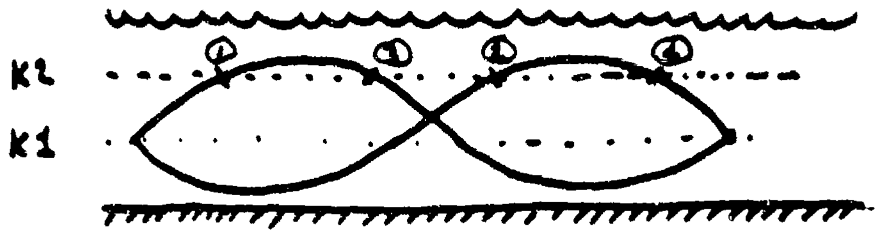


ICOH = 0

FACTTL - Coherence Geometry for Combining Ray Paths
8 of 8

KFLAG = 1

(K1 deeper than K2)



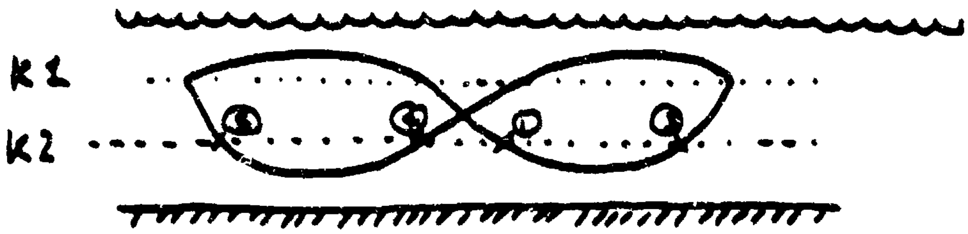
		ORDERING OF RANGES FOR ISCOH VALUES		
NORDER	NP	0	2	3
0	1	1	1	1
	2	3	–	–
1	1	2	2	2
	2	4	1 + P	–
	3	1 + P	–	–
	4	3 + P	–	–
2	1	2 + P	2 + P	2 + P
	2	4 + P	1 + 2·P	–
	3	1 + 2·P	–	–
	4	3 + 2·P	–	–
3	1	2 + 2·P	2 + 2·P	2 + 2·P
	2	4 + 2·P	1 + 3·P	–
	3	1 + 3·P	–	–
	4	3 + 3·P	–	–

etc. etc.

FACTTL - Ray Path Range Selection
1 of 8

KFLAG = 1

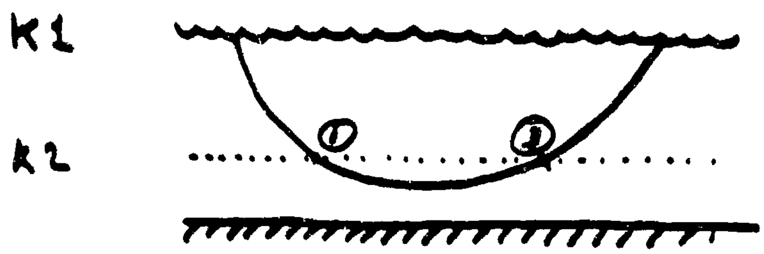
(K2 deeper than K1)



NORDER	NP	ORDERING OF RANGES FOR ICON VALUES: 0	1	3
0	1	2	2	5
	2	1	–	–
1	1	4	4	4
	2	3	2 + ρ	–
	3	2 + ρ	–	–
	4	1 + ρ	–	–
2	1	4 + ρ	4 + ρ	4 + ρ
	2	3 + ρ	2 + 2·ρ	–
	3	2 + 2·ρ	–	–
	4	1 + 2·ρ	–	–
3	1	4 + 2·ρ	4 + 2·ρ	4 + 2·ρ
	2	3 + 2·ρ	2 + 3·ρ	–
	3	2 + 3·ρ	–	–
	4	1 + 3·ρ	–	–

etc. etc.

KFLAG = 2

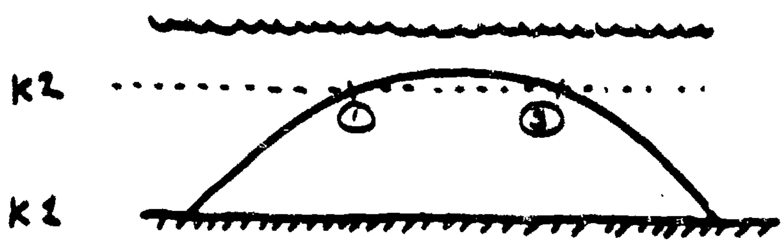


		ORDERING OF RANGES FOR ICOH VALUES	
IORDER	NP	0	1
0	1	1	1
1	1	3	3
	2	1 + ρ	—
2	1	3 + ρ	3 + ρ
	2	1 + 2 ρ	—
3	1	3 + 2·ρ	3 + 2·ρ
	2	1 + 3·ρ	—

etc. etc.

FACTTL - Ray Path Range Selection
3 of 8

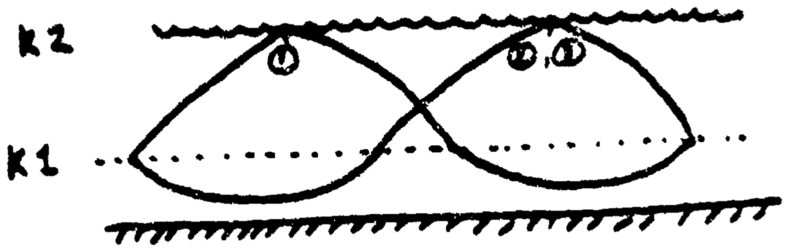
KFLAG = 3



		ORDERING OF RANGES FOR ICOM VALUES	
NORDER	NP	0	1
0	1	1	1
	2	2	-
1	1	1 + P	1 + P
	2	2 + P	-
2	1	1 + 2·P	1 + 2·P
	2	2 + 2·P	-
3	1	1 + 3·P	1 + 3·P
	2	2 + 3·P	

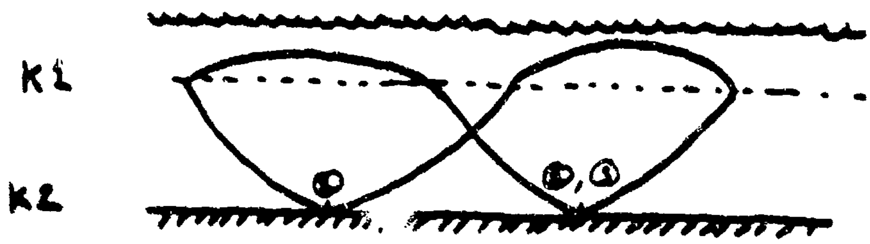
etc. etc.

KFLAG = 4



		ORDERING OF RANGES FOR ISCON VALUES	
NORDER	NP	0	1
0	1	1	1
1	1	2	1
	2	1 + P	—
2	1	2 + P	2 + P
	2	1 + 2 P	—
3	1	3 + 2·P	2 + 2·P
	2	1 + 3 P	—

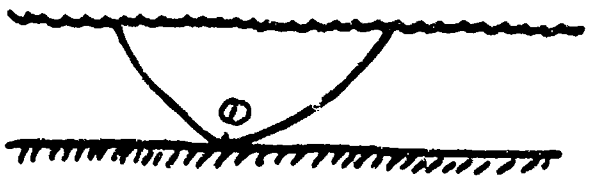
KFLAG = 5



		ORDERING OF RANGES FOR ICOH VALUES	
NORDER	UP	0	1
0	1	2	2
	2	1	–
1	1	2 + ρ	2 + ρ
	2	1 + ρ	–
2	1	2 + 2·ρ	2 + 2·ρ
	2	1 + 2·ρ	–
3	1	2 + 3 ρ	2 + 3·ρ
	2	1 + 3·ρ	–

etc. etc.

KFLAG = 6

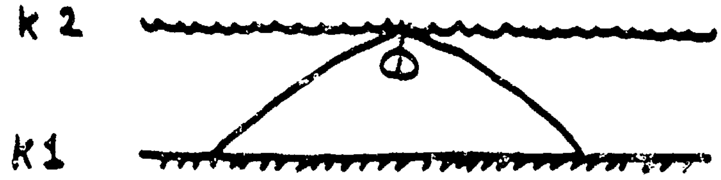


ICOH = 0

NORDER	NP	ORDERING OF RANGES
0	1	①
1	1	① + P
2	1	① + 2·P
3	1	① + 3·P
4	1	① + 4·P
5	1	① + 5·P

etc

KFLAG =7



ICOH = 0

NORDER	NP	ORDERING OF RANGES
0	1	1
1	1	1 + P
2	1	1 + 2·P
3	1	1 +3·P
4	1	1 +4·P
5	1	1 +5·P
etc		etc

FACTTL - Ray Path Range Selection
8 of 8

SUBROUTINE SHALTL

SHALTL is a self-contained model for estimating shallow-water (less than 1000 feet) transmission loss for bottom-class/frequency combinations permitting perfect reflection of rays at grazing angles on the bottom less than some critical angles. A trivial modification to TLOSS will cause SHALTL to be called in place of FACTTL for these combinations which may be followed for a call to FACTTL for the remaining cases. Note that a single frequency is processed by each call to SHALTL.

SHALTL assumes a homogeneous (uniform sound velocity) medium and includes an average surface image interference effect. A simplified bottom-loss approximation assumes a bottom which is perfectly reflecting to a critical angle THCDG. Above this angle, the bottom has a constant loss FL90 for the first order path and is perfectly absorbing for higher order paths. The constants THCDG and FL90 are chosen from 3x3 arrays as a function of bottom type (1-3) and frequency band (0-150 Hz, 151-699 Hz, and 700-1000 Hz).

PARAMETER INPUTS

YS	Source depth, feet	D	Bottom depth, feet
YR	Receiver depth, feet	NR	No. of range points, ≤250
F	Frequency, Hz	DR	Incremental range, feet
IB	Bottom type, 1-3		

PARAMETER OUTPUT

TL Array (250) of transmission loss versus range, dB re 1 yard

SUBROUTINE INSERT

INSERT is called by FACTTL at the beginning of each case to process the input sound velocity profile. INSERT corrects all depths and velocities to account for spherical-earth effects, and ensures that explicit points for source and receiver depths are inserted in the profile and that they are at points of unequal sound velocity. Prior to inserting these source and receiver depths in the profile, INSERT calls AXIS to account for axis-to-axis transmission; this call may result in the source and receiver depths being changed. For ray-tracing purposes, INSERT chooses, from these two depths, the point with the lesser sound speed as the source for ray-tracing purposes; throughout the remainder of the FACT program, the term source refers to this point. Three indices are set by INSERT as the result of this processing: K1, the index of the ray-tracing source; K2, the index of the ray-tracing receiver; and KRC (=1 or 2) indicating which of these is the depth at which arrival angles are to be calculated.

INSERT constructs the final sound velocity profile in common area /VELOC/ and the gradients of this profile in common area /GRADS/.

PARAMETER INPUTS

Y1	Source depth, feet
Y2	Receiver depth, feet
NPTS	No. of points in sound velocity profile ≤ 50

INSERT (Cont'd)

YX	Array (50) of profile depths, feet
CX	Array (50) of profile velocities, feet per second
IPRNT	Debugging print flag

COMMON INPUTS

/INIT/	IML	Index of mixing layer in profile YX,CX

PARAMETER OUTPUTS

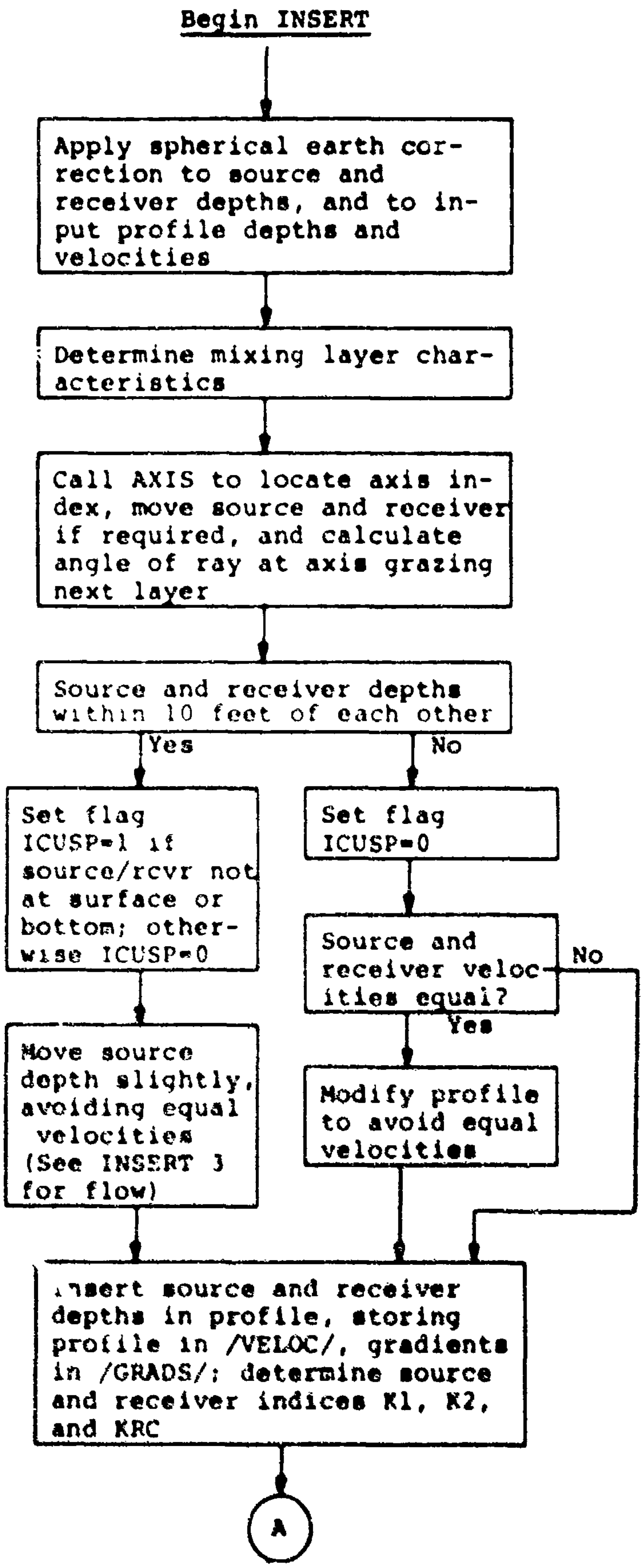
Y1	Corrected source depth, feet
Y2	Corrected receiver depth, feet
KRC	Flag indicating arrival angle depth

COMMON OUTPUTS

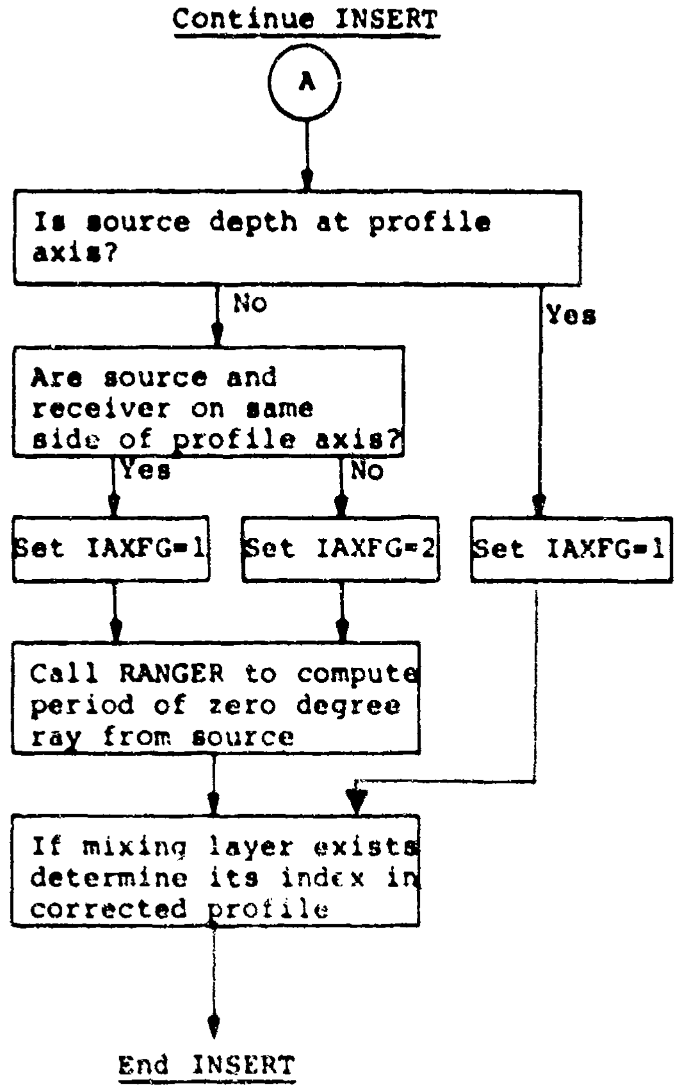
/VELOC/	NPTSP	No. of points in temporary
	YPP	Array (60) of corrected profile depths, feet
	CPP	Array (60) of corrected profile velocities, feet per second
/GRADS/	G	Array (60) of profile gradients, (sec^{-1})
/INIT/	K1	Index of ray tracing source in corrected profile
	K2	Index of ray tracing receiver in corrected profile
	YML	Mixing layer depth in corrected profile
	IMLP	Index of mixing layer in corrected profile
	G1	Gradient above mixing layer in corrected profile
	G2	Gradient below mixing layer in corrected profile

INSERT (Cont'd)

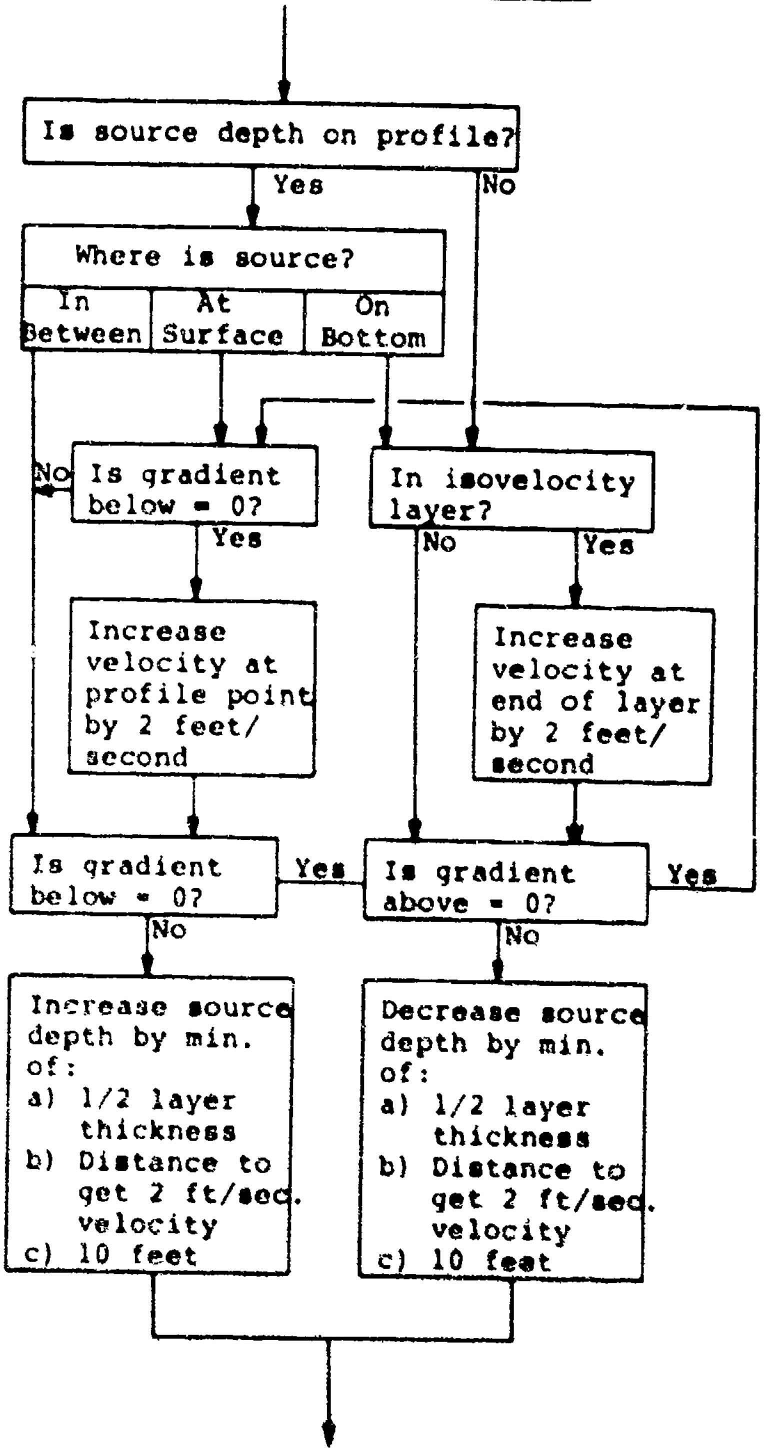
/CUSPCM/	ICUSP	Cusped caustic flag
/PERIOD/	PERO	Period of zero degree traced from K1
	IAXFG	Flag indicating source-receiver-axis geometry
	COSA ANGP	Limiting ray angle (at axis) for analytic low frequency cutoff, and its cosine


Begin INSERT
Apply spherical earth correction to source and receiver depths, and to input profile depths and velocities
Determine mixing layer characteristics
Call AXIS to locate axis index, move source and receiver if required, and calculate angle of ray at axis grazing next layer
Source and receiver depths within 10 feet of each other
Yes
No
Set flag ICUSP=1 if source/rcvr not at surface or bottom; otherwise ICUSP=0
Set flag ICUSP=0
Source and receiver velocities equal?
No
Yes
Move source depth slightly, avoiding equal velocities (See INSERT 3 for flow)
Modify profile to avoid equal velocities
Insert source and receiver depths in profile, storing profile in /VELOC/, gradients in /GRADS/; determine source and receiver indices K1, K2, and KRC
A

INSERT 1


Continue INSERT
A
Is source depth at profile axis?
No
Yes
Are source and receiver on same side of profile axis?
Yes
No
Set IAXFG=1
Set IAXFG=2
Set IAXFG=1
Call RANGER to compute period of zero degree ray from source
If mixing layer exists determine its index in corrected profile
End INSERT

INSERT - Move Source Depth Slightly



SUBROUTINE AXIS

AXIS is called from INSERT to determine the parameters required to handle axis-to-axis transmission. Initially, the deep sound channel axis is located (if present) and the smaller of the two velocities immediately to either side of the axis is obtained. This information is used to fit a smooth (quadratic) function to the velocity profile which is continuous in velocity and gradient at the axis. The period of the zero-degree ray at the axis is then determined as an analytic function of the smoothed-profile coefficients. Subsequently, the angle of the ray which has the same period in the linearly-segmented profile is determined by means of a simple closed-form expression. If the two turning-point (vertex) depths of this ray about the axis bound both the source and receiver depths, then the source and receiver depths are required to take on the depth value of one of the turning points.

When no axis exists, the "axis" depth index is set either to the surface or to the bottom, and the period of the zero degree ray (PERO) is set to 0.

Following the above calculations, AXIS determines the limit angle for analytical low-frequency cut-off effects. This angle is the angle of the ray at the axis which just grazes the next layer in the velocity profile.

AXIS (Cont'd)

PARAMETER INPUTS

YS	Source depth, feet
YR	Receiver depth, feet
IPR	Debugging print flag

COMMON INPUTS

/VELOCX/	NPTS	No. of points in sound velocity profile
	Y	Array (60) of profile depths, feet
	C	Array (60) of profile velocities, ft/sec

PARAMETER OUTPUTS

YS	Adjusted source depth, feet
YR	Adjusted receiver depth, feet

COMMON OUTPUTS

/PERIOD/	YUP*	Minimum depth of axis ray, feet
	YDN*	Maximum depth of axis ray, feet
	PERO	Period of axis ray, feet
	COSA	Limit angle at axis for analytical
	ANGP	low-frequency cutoff, radians, and its cosine
	LX	Index of axis in profile

*LX ≠ 0 or NPTS only

SUBROUTINE TABTH2

TABTH2 is called by FACTTL to tabulate the ray angle at the bottom, θ_B, as a function of the ray angle at the receiver depth, θ_{K2}. Twenty-one equally-spaced values of θ_{K2} are tabulated, from θ_{Min} to $\pi/2$, along with the corresponding (unequally-spaced) values of θ_B. The value of θ_{Min} is that of the first ray which touches the bottom. For ease in interpolation (by function THBOT), the ratios of the corresponding increments in the two tables are also tabulated.

PARAMETER INPUT

CBC2	Ratio of bottom velocity to receiver depth velocity

COMMON OUTPUTS

/TH2TAB/	TH2MIN	Minimum ray angle at receiver depth
	FACTOR	Reciprocal of increment in θ_{K2}
	TH2T	Array of 21 values of θ_{K2}
	THBT	Array of 21 values of θ_B
	RATIO	Array of 20 ratios of $\Delta\theta_B/\Delta\theta_{K2}$

SUBROUTINE CRITA

CRITA is called by FACTTL to compute the WKB phase factors for low-frequency cutoff effects. The deep-sound channel is first located (as in subroutine AXIS), and subroutine RAYT is called to compute the relative phase of the ray along the axis with initial angle such that the next layer in the profile is just grazed (this is the limit angle for analytical cut-off effects which was calculated by AXIS) CRITA then determines the relative phases for each frequency being processed, using analytical expressions for rays at less than the limiting angle, and by iteration (using RAYT) for rays crossing more than one layer in the profile. For each frequency attenuation factors are calculated in the form of beam patterns (amplitude vs. angle); these are analytic for rays below the limit angle and tabulated for rays above the limit angle. An array of flags is also produced for rapid determination (in INSTOR and CUSP) of which beam pattern type applies at each frequency.

PARAMETER INPUT

IPR	Debugging print flag

COMMON INPUTS

/VELOC/	LMAX	No. of points in profile
	Z	Array (60) of profile depths, feet
	V	Array (60) of profile velocities, ft/sec

CRITA (Cont'd)

/INIT/	L	Index of source depth in profile
/RANGEL/	NFREQ	No. of frequencies
	IFQMIN	Index of lowest frequency
	FQ	Array (6) of frequencies, Hz
/PERIOD/	COSA, ANGP	Limit angle for analytical beam patterns, radians, and its cosine

COMMON OUTPUTS

/CRIT/	BEE2	Coefficient of analytic low-frequency cut-off amplitudes
	C1	Velocity at source (K1), ft/sec
	CX	Velocity at profile axis, ft/sec
	JALF	All frequencies - analytical flag
	JAIF	Array (6) of individual analytical frequency flags
	CRITANX	Array (6) of critical angles vs. frequency
	CAX	Array (6,4) of beam pattern angles vs. frequency
	SS	Array (6,4) of beam pattern amplitudes vs. frequency

SUBROUTINE RAYT

RAYT is called from CRITA to determine the relative phase (in terms of travel time) along a ray traced over one cycle, adjusted, if required, to account for surface and/or bottom reflections.

PARAMETER INPUTS

LA	Index of source in velocity profile
COSTHO	Cosine of initial ray angle

COMMON INPUTS

/VELOC/	LMAX	No. of points in velocity profile
	Z	Array (60) of profile depths, feet
	C	Array (60) of profile velocities, ft/sec
/GRADS/	G	Array (60) of profile gradients, (sec^{-1})

PARAMETER OUTPUT

CUTOFF	Relative phase of ray, seconds

SUBROUTINE ANGSCH

ANGSCH is called from FACTTL to determine the families of rays to be processed, as a function of the sound velocity profile, and the source and receiver depths. Each family is chosen so that a smooth fit of ray range vs. ray angle can be made. Up to 100 rays in up to 20 families are allowed; if profile and source/receiver data cause these maxima to be exceeded, a diagnostic message is printed (on FORTRAN unit 6) and a flag is set to indicate this condition. The ray angles, in radians, are stored in a single array, THETA. The array IGRP is used to designate the index of the first ray in each family, and a second array, IGRAZE, indicates that the first ray in family just grazes a specified profile point.

The rays in each group are constrained to be at least three in number, with a maximum spacing of .5 degrees. A new family begins when a relative maximum in the profile is encountered, when either the surface or bottom is encountered, and when the profile gradient decreases by more than a specified increment.

COMMON INPUTS

/VELOC/	NPTS	No. of points in sound velocity profile
	Y	Array (60) of profile depths, feet
	C	Array (60) of profile velocities, ft/sec

ANGSCH (Cont'd)

/GRADS/	G	Array (60) of profile gradients, (sec^{-1})
/INIT/	K1	Index of source depth in profile
	K2	Index of receiver depth in profile
	YML	Mixing layer depth, feet
	IMLP	Index of mixing layer depth in profile
	IML	Index of mixing layer (as input)
/RAYZER/	THBINC	Bottom angle increment ($=5^{o}$), radians
	THETMB	Critical angle for FNWC bottom type, radians

COMMON OUTPUTS

/RAYZER/	IRFFRZ	Flag indicating grazing ray at K2
/CUSPCM/	ICUSP	Flag indicating cusped caustic (turned off if source and receiver within mixed layer)
/ANGLES/	NRAYS	Number of rays in all families $\leq$ 100 or 999
	NGRPS	Number of families of rays $\leq$ 20
	ISURF	Index of first ray of hit surface
	IBOT	Index of first ray to hit bottom
	IGRP	Array (20) of indices of first ray in each family
	IGRAZE	Array (20) of grazing flags
	THETA	Array (100) of initial ray angles, radians

SUBROUTINE RANGER

RANGER is called from FACTTL, INSERT, and AXIS to compute the ranges associated with one up- and down-going cycle of a ray traced from the source depth (K1). The initial ray angle is positive if possible (source not at the surface) and is traced for a quarter-cycle, or until the ray hits the surface; the process is then repeated for a ray with negative angle if possible (source not at the bottom). As these rays are traced, RANGER calculates depth versus range; the crossings, if any, of the receiver depth (K2) are noted, and the corresponding ranges are saved.

The outputs from RANGER are the period of the ray, the maximum and minimum depths attained by the ray, and the distances to the first and second crossings of the receiver depth. If the receiver depth is not reached, these are instead the ranges to the first and second crossings of the source level, i.e., the half- and full-period ranges.

COMMON INPUTS

/VELOC/	NPTS	No. of points in sound velocity profile
	Y	Array (60) of profile depths, feet
	C	Array (60) of profile velocities, ft/sec
/GRADS/	G	Array (60) of profile gradients, (sec^{-1})
/INIT/	K1	Index of source depth

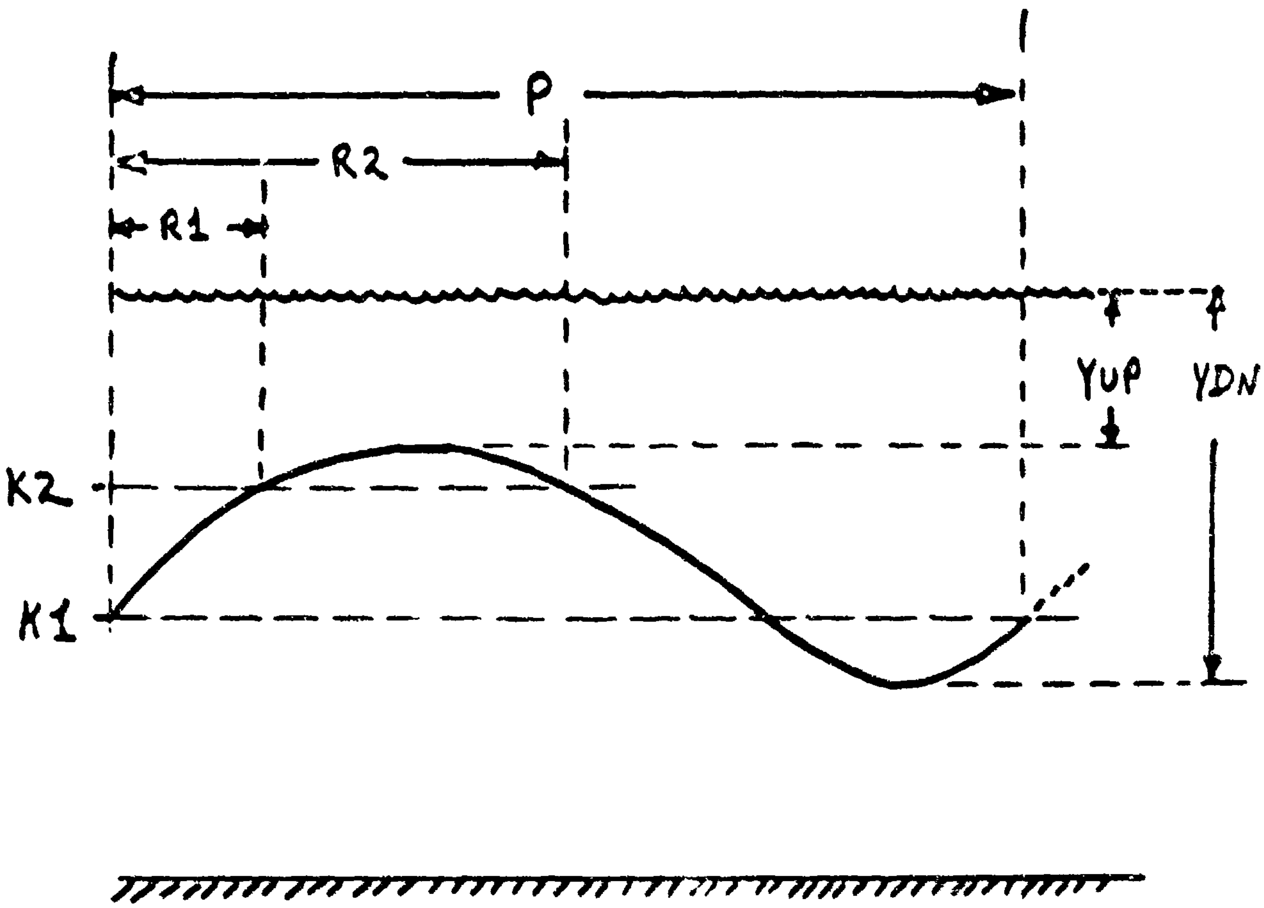
/INIT/	K2	Index of receiver depth
	AK	Vertex velocity of ray being traced, ft/sec
	SINTHO	Sine of initial ray angle at K1

PARAMETER OUTPUTS

	R1	Range of first crossing of receiver depth, feet
	R2	Range of second crossing of receiver depth, feet
	P	Full-cycle period of ray, feet

COMMON OUTPUTS

/PERIOD/	YUP	Minimum depth attained by ray, feet
	YDN	Maximum depth attained by ray, feet



RANGER - Geometry for Ray Tracing

SUBROUTINE FITBOT

FITBOT is called by FACTTL to determine the coefficients of the fit of range vs. ray angle at the receiver (θ_{K2}) for the last (bottom- and surface-reflecting) family. For rays with bottom angles less than 30°, the form of the fit is:

$$R = A(1) + A(2)*(\theta_{K2}-\theta_{Min})^{\frac{1}{2}} + A(3)*(\theta_{K2}-\theta_{Min})$$

For bottom angles greater than 30°, the form of the fit is:

$$R = \frac{1}{A(4)*TAN(\theta_{K2}) + A(5)}$$

All coefficients are calculated by FITBOT with the exception of A(4) which is calculated in FACTTL to give the correct limiting range for the (implicit) 90° ray. The derivatives of R vs. θ_{K2} are continuous at the value of θ_{K2} corresponding to the 30° bottom ray.

PARAMETER INPUTS

R	Array (2) of ranges to be fit, feet
TH	Array (2) of angles (at K2) to be fit, radians
A	Array value [A(4)] of coefficient determined in FACTTL

PARAMETER OUTPUTS

A Array values [A(1), A(2), A(3), A(5)] of coefficients of fit of range vs. ray angle

SUBROUTINE FINDFT

FINDFT is called by FACTTL to determine the coefficients of the fit of ray range vs. ray angle at the receiver for all families except the last (bottom- and surface-reflected) family. The form of the fit is:

$$R = A(1) + A(2)*X(\theta_{K2}) + A(3)* [X(\theta_{K2})]^2$$

The form of the function $X(\theta_{K2})$ depends upon the value of IPAR:

$$\text{IPAR} = 1: \quad X(\theta_{K2}) = \text{TAN}(\theta_{K2})$$

$$\text{IPAR} = 2: \quad X(\theta_{K2}) = (\theta_{K2} - \theta_{Min})^{\frac{1}{2}}$$

Three points are used in the fit: The minimum and maximum values of θ_{K2}, plus a third point which is the value of θ_{K2} which gives a minimum or maximum value of range within the region of interest, or, if no minimum or maximum exists, the value of θ_{K2} corresponding to the second ray in the family. For families with grazing rays at the receiver (Flag IREFRZ = 1), the three values of θ_{K2} are 0, and the values $\pm\theta_{K2}$ corresponding to the last ray in the family.

FINDFT also sets various parameters giving ranges in range, angle, and X, over which the fit of range vs. angle is valid. See the documentation of INSTOR for a diagram showing the notation employed (page 4-83).

FINDFT (Cont'd)

PARAMETER INPUT

	IPRNT	Debugging print flag

COMMON INPUTS

/FLAGS/	C1C2	Ratio of source depth velocity to receiver depth velocity
/INPUTS/	KRAY	No. of rays in family being fit, ≤ 100
	KP	Index of ray paths in array R, 1-4
	NORDER	Arrival order being processed
	NG	Index of family being fit, ≤ 20
	IPAR	Flag indicating functional form of fit
	R	Array '100,4) of ray ranges vs. source angle and path index, feet
	TH	Array (100) of ray source angles, radians
/INIT/	K1	Index of source depth
	K2	Index of receiver depth
/RAYZER/	IREFR2	Flag indicating first ray grazes receiver depth
/CUSPCM/	ICUSP	Flag indicating cusped caustic

COMMON OUTPUTS

/FLAGS/	THMIN	Angle at receiver of shallowest (at source) ray, radians
	THMAX	Angle at receiver of steepest (at source) ray, radians
/FITS/	THF	Array (3) of receiver ray angles, radians

/FITS/	RF	Array (3) of ranges of fit, feet
	A	Array (3) of coefficients of fit
	XMIN	Value of X(THMIN)
	XMAX	Value of X(THMAX)
	RMIN	Range corresponding to THMIN
	RMAX	Range corresponding to THMAX
	RANMIN	Minimum range spanned by fit, feet

SUBROUTINE FITQ

FITQ is called by FINDFT and CUSP to determine the coefficients of the quadratic function

$$Y = A(1) + A(2)*X + A(3)*X^2$$

which passes through the three points X(1),Y(1); X(2),Y(2); and X(3),Y(3), where X(1) $\neq$ X(2) $\neq$ X(3) $\neq$ X(1).

PARAMETER INPUTS

X	Array (3) of ordinate values
Y	Array (3) of abscissa values

PARAMETER OUTPUTS

A	Array (3) of coefficients of fit

SUBROUTINE INSTOR

INSTOR is called by FACTTL to add the intensity contributions arising from one arrival of one order of one family of rays to each applicable point in array TL over the range of interest. INSTOR is also called by CUSP to process any smooth caustic which may be associated with a cusped caustic.

The range interval is determined by the coefficients and parameters of the fit of range vs. (receiver) ray angle, calculated by FACTTL or CUSP and passed through common areas /FITS/ and /FLAGS/. The contribution of each arrival (which may actually represent several arrivals) at a given range point within this interval is subsequently added to the array TL by:

TL(Range,Freq) = TL(Range,Freq) + FACT/XL(Freq)

XI is the reciprocal ray intensity and is determined from one of four arrival geometries; FACT is a modifying factor (in the range 0-4) which accounts for the effects of in-, semi-, or fully-coherent combination of multiply-combined arrivals under the ICOH and IFLAG options. XI may also be modified to account for bottom-bounce losses and low-frequency cut-off effects.

The four arrival geometries and the corresponding reciprocal intensity factors are as follows. See relevant geometry diagrams on pages 4-83, 96 and 97.

1) Single-ray (no caustic) arrival:

XI(freq) = XIT1 = RANGE(K)*SIN1(1)*RP/COS2

where:

RANGE(K) = Range in feet, R

SIN1(1) = $|\sin\theta_{K1}|$ (θ_{K1} = ray angle at source)

COS2 = $|\cos\theta_{K2}|$ (θ_{K2} = ray angle at receiver)

RP = $|dR/d\theta_{K2}|$ at range R

2) Shadow zone of a smooth caustic:

XI(freq) = XIC(freq)*FAIRY(XAIR)*RANGE(K)/RC

Using:

XIC(freq) = XIC1*FREQ(freq)

XIC1 = CONST*SINC1*RC*(ABS(RPP**2/SINC))**(1./3.)/COSC

XAIR = -BETA(freq)*DRAIR*FACTOR

BETA(freq) = BETA1/FREQ(freq)**2

DRAIR = ABS(RC-RANGE(K))

FACTOR = 1./(COS(1.57079*ABS(DRAIR/(RCUT-RC)))), IRFG=1
= 1. , IRFG=0

BETA1 = (2.*(SINC/5000.)**2/ABS(RPP))**(1./3.)

where:

RANGE(K) = Range in feet, R

RC = Range of caustic, feet

FREQ = (Radian frequency)$^{-1/3}$

INSTOR (Cont'd)

CONST	=	$C_{K2}^{1/3}/2^{5/3} \cdot \pi \cdot Ai^2(0)$
SINC1	=	$\sin\theta_{K1}$ (θ_{K1} is source angle corresponding to $\theta_C = \theta_{K2}$ at caustic)
RPP	=	$d^2R/d\theta_{K2}^2$ evaluated at range RC
SINC	=	$\sin\theta_C$
COSC	=	$\cos\theta_C$
RCUT	=	Range at which shadow zone is tapered off
IRFG	=	Flag indicated shadow zone tapered off at RCUT
FAIRY(X)	=	Modified Airy function $\approx [Ai(0)/Ai(-X)]^2$

3) Illuminated region of a smooth caustic (no cusped caustic):

XI(freq) = XIC(freq)*FAIRY(XAIR)*2.*RANGE(K)/RC, XAIR $<$ 1.77

= XIT1 , XAIR $\geq$ 1.77

Using:

XAIR = BETA(freq)*DRAIR

XIC(freq) is calculated as in 2) above

XIT1 is calculated as in 2) above

4) Illuminated region of a smooth caustic associated with a cusp:

a) Steep Branch ($|\theta_{K2}| \geq |\theta_C|$):

XI(freq) is calculated as in 3) above

b) Shallow Branch ($|\theta_{K2}| < |\theta_C|$):

XI(freq) = AMIN1(XI(freq), XICP)

INSTOR (Cont'd)

Using:

XI(freq) = XIC(freq)*FAIRY(XAIR)*2.*RANGE(K)/RC

XICP = XICUSP(RANGE(K),1000.*FREQK(freq))*RANGE(K)/COS2

XIC(freq) is calculated as in 3) above

Where:

FREQK(freq) = Frequency in Hz

XICUSP(X) = Intensity Function - see CUSP, page 4-93

In addition to calculating the intensity contributions as outlined above, INSTOR determines when these are no longer significant, thus signaling the end of the loop on NORDER in FACTTL. This condition arises when the intensities fall below a minimum value, or when the range of an order is greater than the maximum range of interest. Flag IGTYP in common area /FLAGS/ is set negative to indicate that this has occurred.

Arrival information (range, ray angle, and ray intensities at each frequency) is calculated and written on file IARVTP if this flag is not zero.

PARAMETER INPUTS

KRC	Flag indicating arrival angle depth
SNTHR	Sign of ray angle at depth flagged by KRC
IP	Debugging print flag
IARVTP	Flag indicating file for arrival information output

INSTOR (Cont'd)

PARAMETER OUTPUTS

TL Array (250,6) of intensities vs. range and frequency

FILE OUTPUT

Unit IARVTP One record for each arrival angle at each range point. The format of each BCD record is as follows:

Position	Format	Contents
1	1H	Blank
2-7	F6.1	Range, Nautical Miles
8-9	2X	Blank
10-16	F7.3	Arrival Angle, Degrees
17-18	2X	Blank
19-23	F5.1	Loss at 1st Frequency, dB
24-25	2X	Blank
26-30	F5.1	Loss at 2nd Frequency, dB
etc	etc	etc
52-58	F5.1	Loss at 6th Frequency, dB

COMMON INPUTS

/FLAGS/	IGTYPP	Type of family (fit) being processed
	THMIN	Shallowest ray angle in family being processed
	THMAX	Steepest ray angle in family being processed
	CONST	Coefficient for caustic intensities

INSTOR (Cont'd)

	C1C2	Ratio of source velocity/receiver velocity
	CBC2	Ratio of bottom velocity/receiver velocity
	ICOH	Flag indicating combination of arrivals
	IRSR	Flag indicating surface-reflected rays
	NBOT	No. of bottom bounces of family
	IBTYP	FNWC bottom type
	IFLAG	Array (6) of coherency flags vs. frequency
	CF	Array (2,6) of semi-coherent phase factors vs. frequency
/FITS/	A	Array (5) of coefficients of fit of R vs. θ
	XMIN	Minimum value of argument of fit
	XMAX	Maximum value of argument of fit
	RMIN	Range of minimum-angle ray in family
	RMAX	Range of maximum-angle ray in family
	RANMIN	Minimum range at which intensities result
/[illegible]/	KP	Index of range of path being processed
	NORDER	Order of arrival of path being processed
/RANGEL/	NRANGE	No. of range points
	NFREQ	No. of frequencies
	IFQMIN	Index of minimum frequency
	FREQ	Array (6) of (radian frequencies)**(-1/3)
	FREQK	Array (6) of frequencies, KHz
	RANGE	Array (250) of range points, feet
/RAYZER/	IRFFRZ	Flag indicating grazing arrival at receiver

INSTOR (Cont'd)

/AUTCOH/	FNMIN	Min. no. of range points per surface-image cycle
	FNMAX	Max. no. of range points per surface-image cycle
	FNXI	Reciprocal of FNMAX-FNMIN
	FNCYC	Array (2,6) of cycles of phase difference of up- and down-going rays at K1 and K2 vs. freq.
/CUSPCM/	ICUSP	Flag = 1 if processing smooth caustic associated with a cusp
/CRIT/	BEE2	Coefficient of analytic low-frequency cut-off amplitudes
	C1	Velocity at source (K1), ft/sec
	CX	Velocity at profile axis, ft/sec
	JALF	All-frequencies-analytical flag
	JAIF	Array (6) of individual analytical frequency flags
	CRITANX	Array (6) of critical angles vs. frequency
	CAX	Array (6,4) of beam pattern angles vs. frequency
	SS	Array (6,4) of beam pattern amplitudes vs. frequency
/PERIOD/	PERO	Period of zero-degree ray at source, feet
	ANGP	Limit angle for analytical beam patterns
	IAXFG	Flag indicating source-receiver-axis geometry

INSTOR (Cont'd)

COMMON OUTPUTS

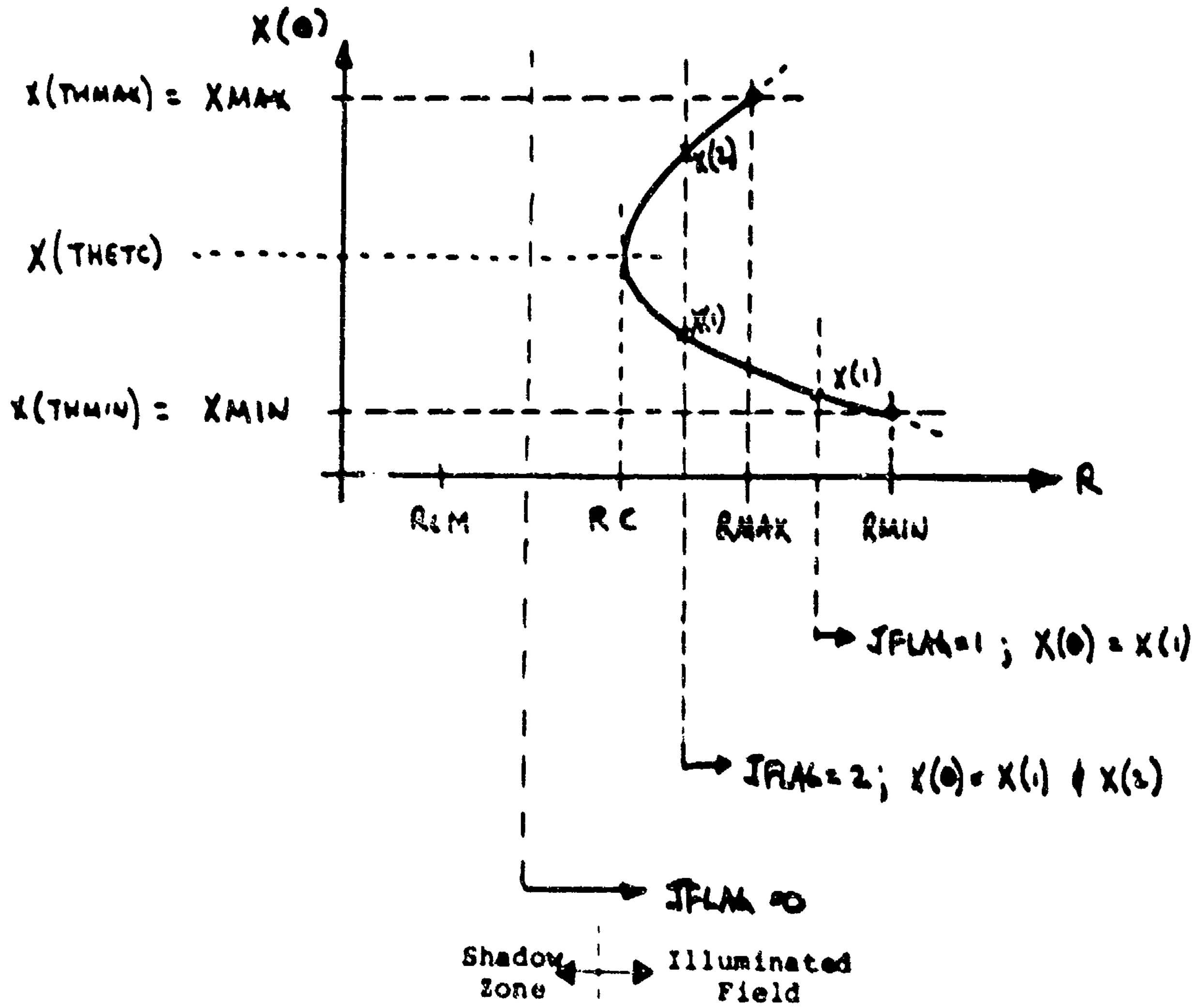
/FITS/	RANMIN	Minimum range at which fit is applicable
/FLAGS/	IGTYPE	Set negative to indicate no contribution to intensity

R is quadratic in $X_1(\theta)$ or $X_2(\theta)$

i.e., $R = A(1) + A(2)*X(\theta) + A(3)*[X(\theta)]^2$

$X_1(\theta) = \text{TAN}(\theta)$ IPAR = 1

$X_2(\theta) = \theta - \theta_{Min}$ IPAR = 2



INSTOR - Fit of R vs. θ

NOTE: Throughout this figure $\theta = \theta_{K2}$ = Ray angle at receiver (K2)

ICOH	SNTHR	NANG	SGN(I) 1	2	3	4
0	(≠0)	4	SNTHR	-	-	-
1 or 2	=0	2	+1.	-1.	-	-
	≠0	2	SNTHR	SNTHR	-	-
3	(=0)	4	-1.	-1.	+1.	-1.

INSTOP - Determination of No. of Arrival Angles and Their Signs

RCUT = [FACTOR IN TABLE (N=NORDER)] *PERO

IREFRZ = 1 so KP $\neq$ 3,4

ICUSP = 0:

IAXFG = 1:

		ICAUST		
		1	2	3
		(NONE)	(MIN RANGE)	(MAX RANGE)
KP =	1	0	N	N+½
	2	0	N-½	N

IAXFG = 2:

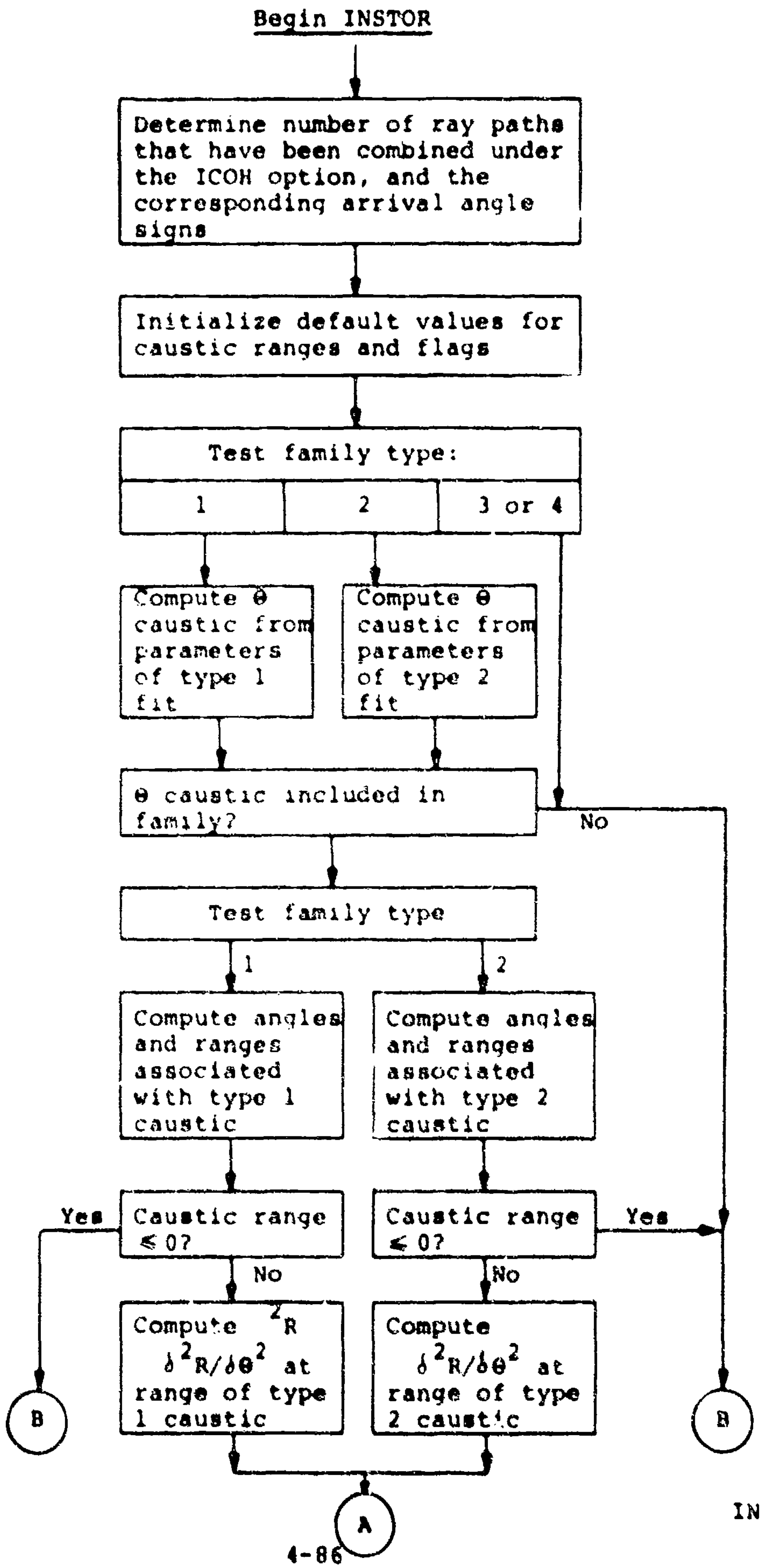
KP =	1	0	N	N+1
	2	0	N	N+1

ICUSP = 1:

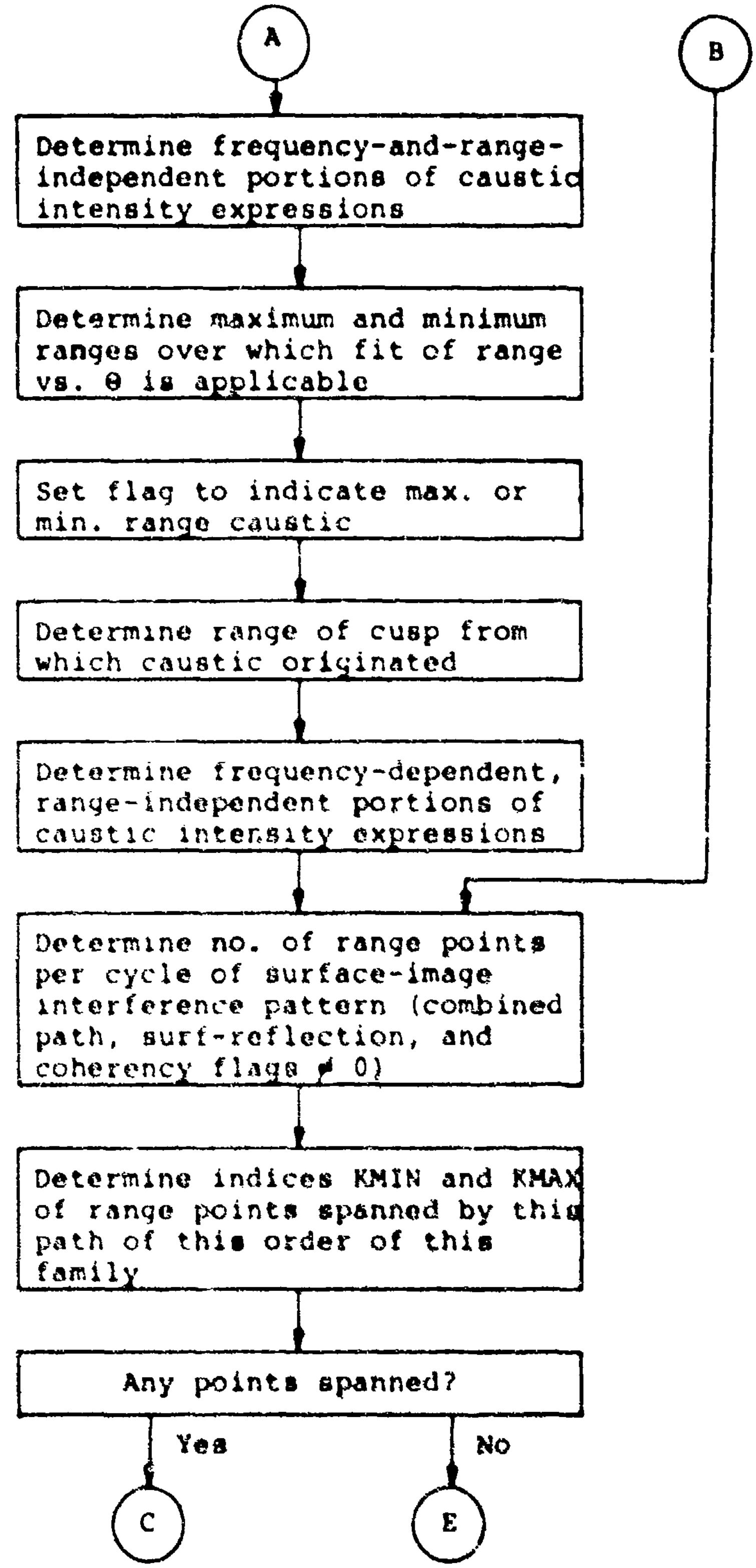
IRSR =	0	0	N-½	N+½
	1	0	N-1	N+1

NOTE: RCUT = 0 if IREFRZ = 0

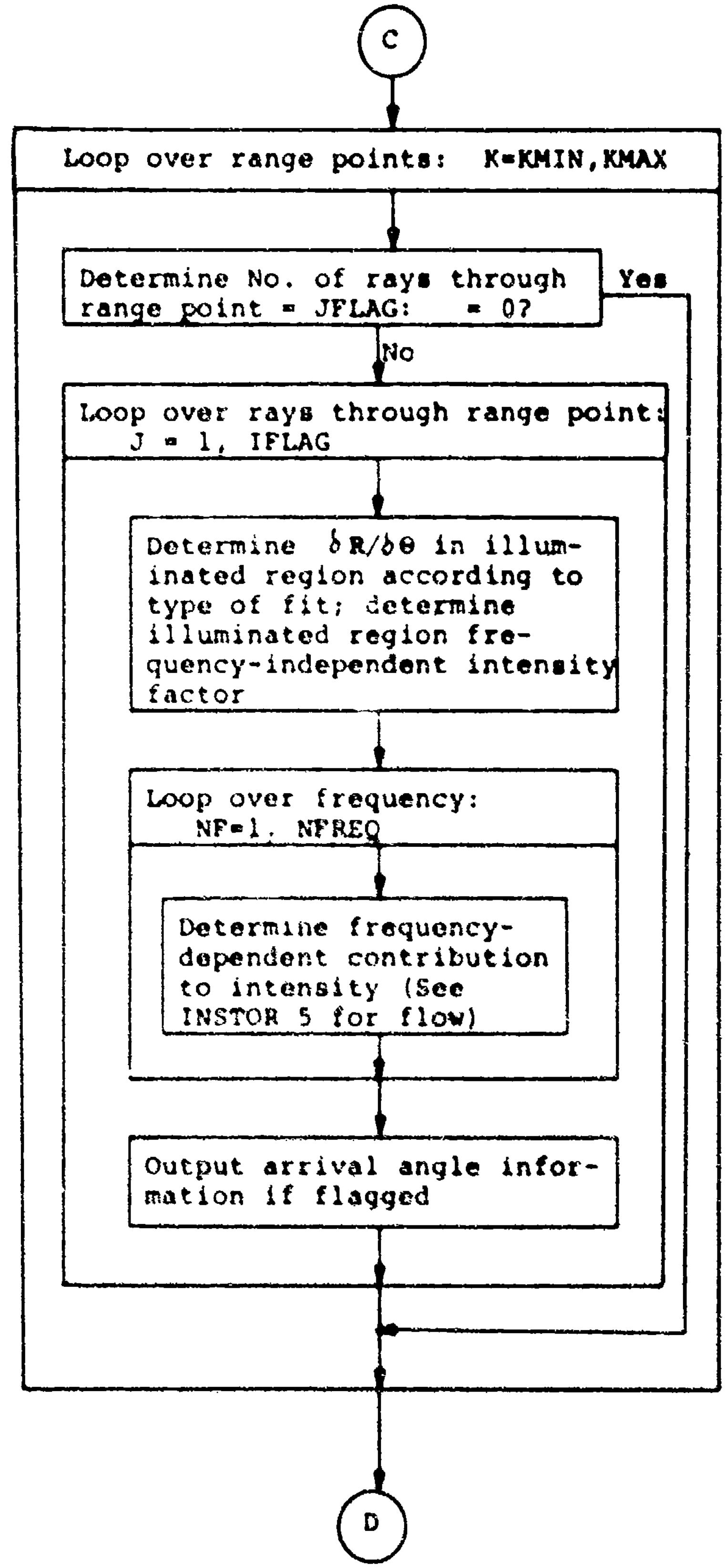
INSTOR - Determination of RCUT


Begin INSTOR
Determine number of ray paths that have been combined under the ICOH option, and the corresponding arrival angle signs
Initialize default values for caustic ranges and flags
Test family type:
1
2
3 or 4
Compute θ caustic from parameters of type 1 fit
Compute θ caustic from parameters of type 2 fit
θ caustic included in family?
No
Test family type
1
2
Compute angles and ranges associated with type 1 caustic
Compute angles and ranges associated with type 2 caustic
Yes
Caustic range ≤ 0?
Caustic range ≤ 0?
Yes
No
No
Compute ∂²R/∂θ² at range of type 1 caustic
Compute ∂²R/∂θ² at range of type 2 caustic
B
B
A

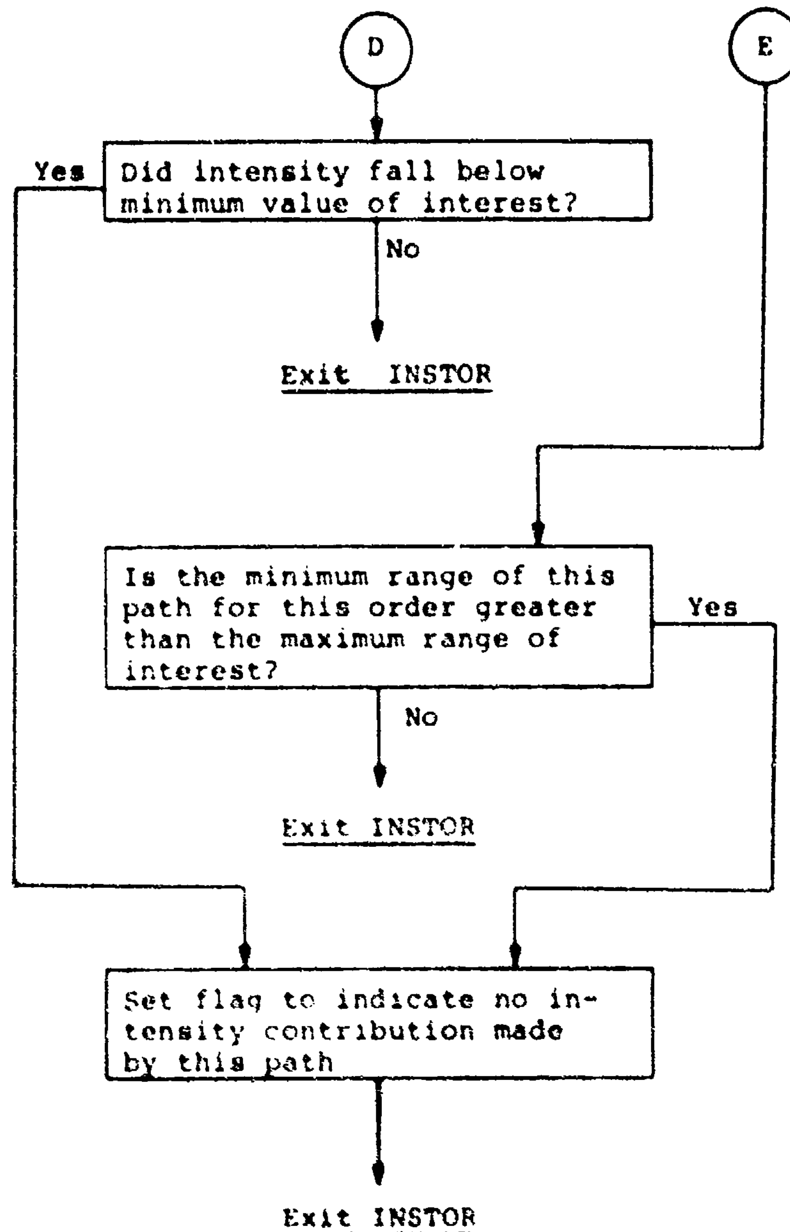
Continue INSTOR



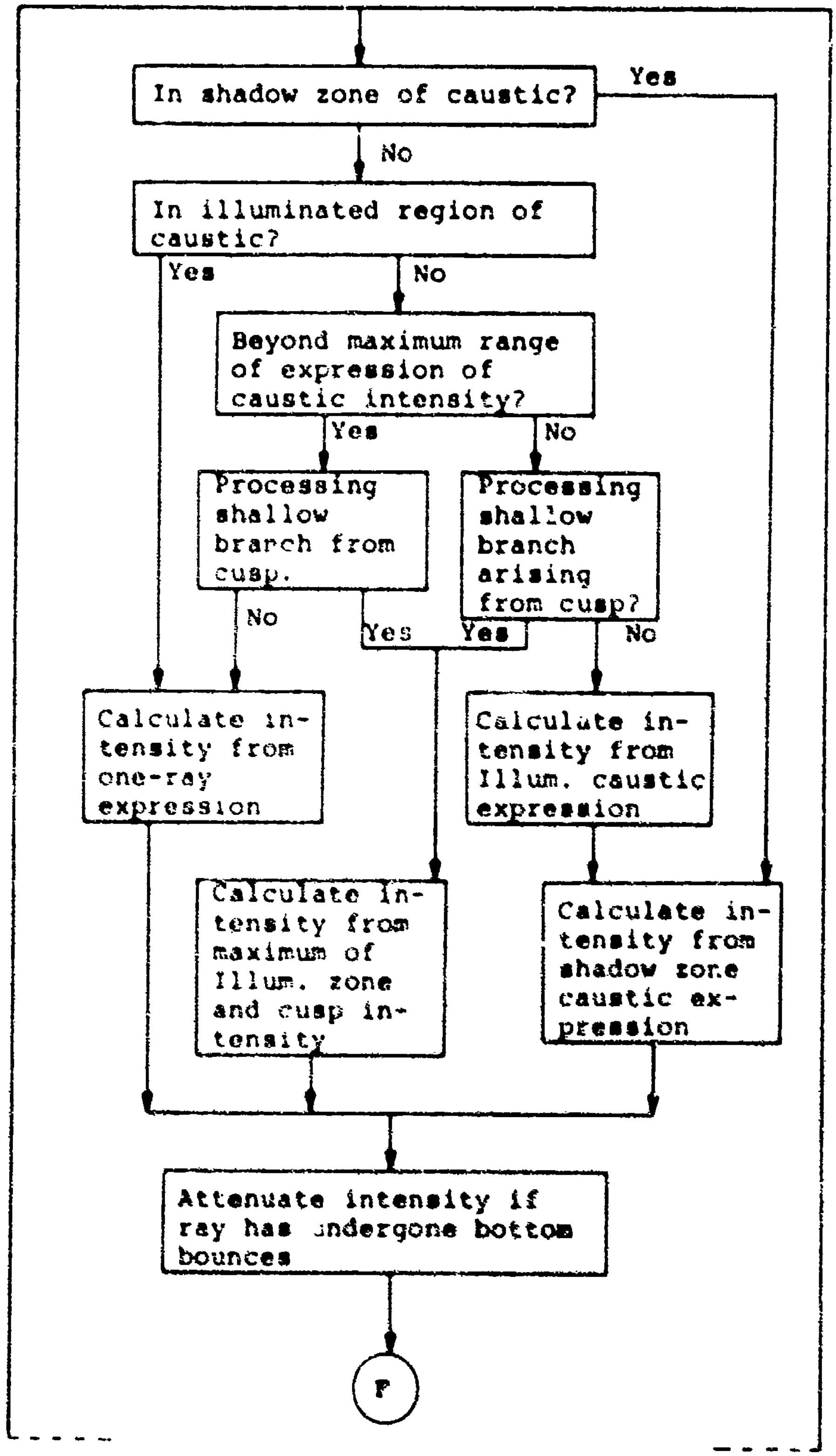
Continue INSTOR



Continue INSTOR

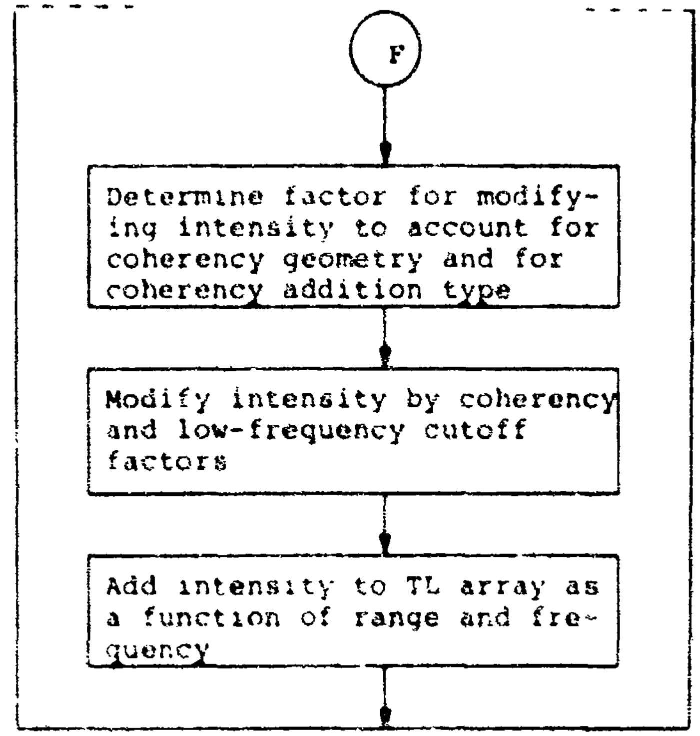


INSTOR - Loop On Frequency



INSTOR 5

Continue INSTOR - Loop on frequency



SUBROUTINE CUSP

CUSP is called by FACTTL to add the intensity contributions arising from each order (other than direct) of a family containing a cusped caustic, to each applicable point in the array TL over the range of interest. CUSP also calls INSTOR to process any smooth caustic which may be associated with a cusped caustic.

The range interval is determined directly from ray path distances for the cusp itself; CUSP also calculates the coefficients and parameters of the fit of range vr. (receiver) ray angle for the smooth caustic (if any) which are passed through common area /FITS/ to INSTOR. For each range point in the interval covered, the intensity contribution to each frequency arising from one arrival order is added to the array TL by:

TL(Range, Freq) = TL(Range, Freq) + 1./XIP(Freq)

XIP is the reciprocal ray intensity and may be modified to account for bottom-bounce losses and low-frequency cutoff effects. It is computed from:

XIP(Freq) = XI(Freq)*RAN/CST

Using:

XI(Freq) = XICUSP(IR,RAN,1000.*FREQK(Freq))

CST = COS(THETA)

Where:

RAN = Range in feet, R

THETA = Angle of ray at range R, estimated from linear or quadratic fit depending upon ray being processed.

XICUSP = Function computing vertical spreading for a ray near the cusp as a function of region (one or three ray), range, and frequency.

IR = 1 in one-ray region, 2 in three-ray region of cusp.

In addition to calculating cusp intensity contributions as outlined above, CUSP determines when these are no longer significant, thus signaling the end of the loop on NORDER in FACTTL. This condition arises when the intensities from the smooth caustics calculated by INSTOR fall below a minimum value, or when the range of an order is greater than the maximum range of interest. Flag IDONE is set to indicate this condition.

Arrival information (range, ray angle, and ray intensities at each frequency) is calculated and written on file IARVTP if this flag is not zero.

PARAMETER INPUTS

K1	Index of source depth
K2	Index of receiver depth
KRC	Flag indicating arrival angle depth

IPRNT	Debugging print flag
IARVTP	Flag indicating file for arrival information output

PARAMETER OUTPUTS

IDONE	Flag indicating end of contribution to intensities
TL	Array (250,6) of intensities vs. range and frequency

FILE OUTPUT

Unit IARVTP	One record for each arrival angle at each range point. See INSTOR for format specifications.

COMMON INPUTS

/INPUTS/	N*	Number of rays in family
	R	Array (100,4) of ranges vs. ray angle and arrival, feet
	TH	Array (100) of ray angles of family, radians
/RANGEL/	NRANGE	No. of range points
	NFREQ	No. of frequencies
	FREQK	Array (6) of frequencies, KHz
	RANGE	Array (250) of ranges, feet
/FLAGS/	IGTYP	Type of family being processed
	NBOT	No. of bottom bounces at this order
	IBTYP	FNWC bottom type
/CUSPCM/	CCUSP	Velocity at cusp, ft/sec
/GRADS/	G	Array (60) of profile gradients, (sec^{-1})

---

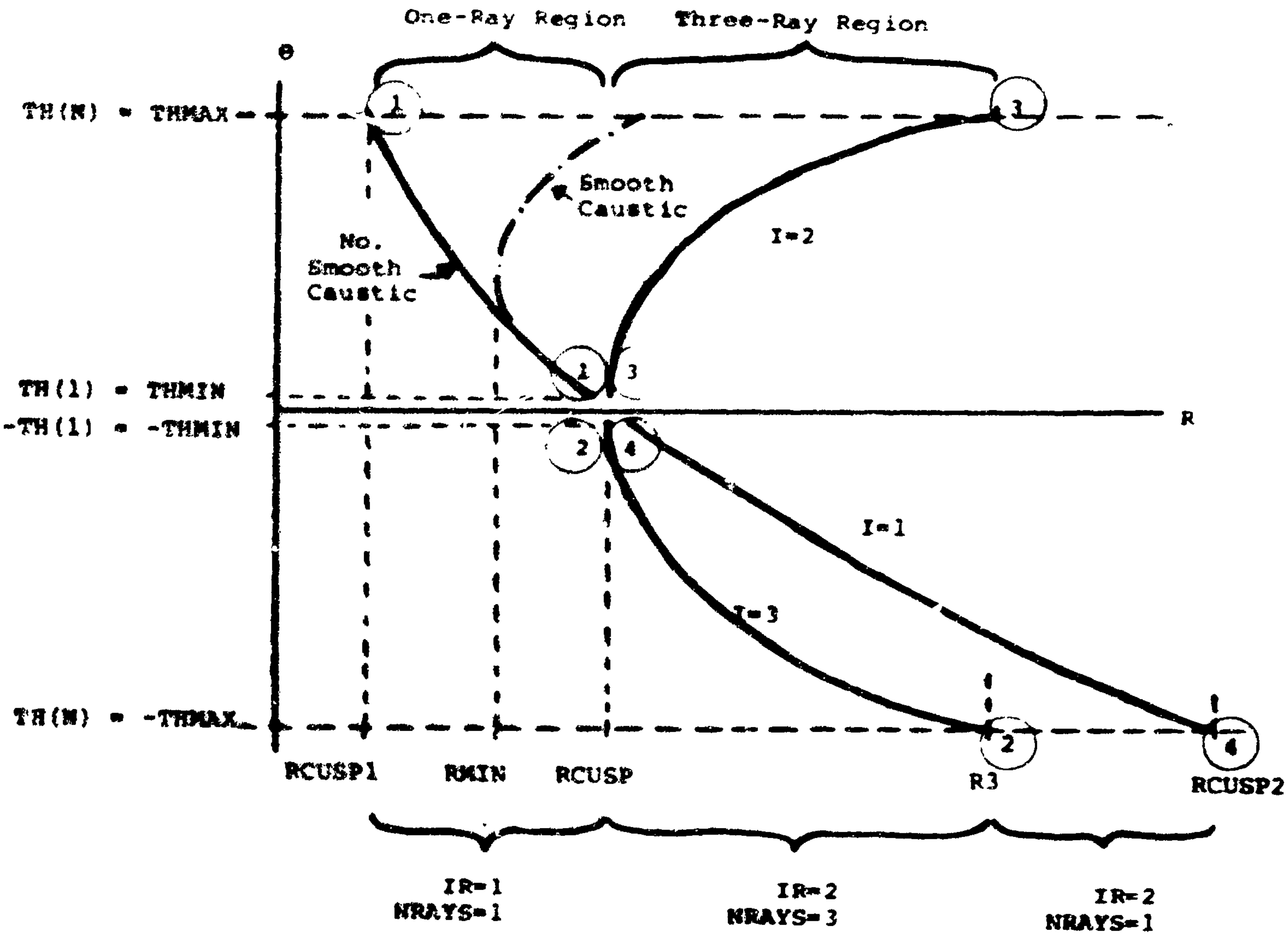
*NRAYS elsewhere

CUSP (Cont'd)

/PERIOD/	ANGP	Limit angle for low-frequency cutoff
/CRIT/	BEE2	Coefficient of low-frequency cut-off amplitudes
	C1	Velocity at source (K1), ft/sec
	CX	Velocity at profile axis, ft/sec
	JALF	All-frequencies-analytical flag
	JAIF	Array (6) of individual analytical frequency flags
	CRITANX	Array (6) of critical angles vs. frequency
	CAX	Array (6,4) of beam pattern angles vs. frequency
	SS	Array (6,4) of beam pattern amplitudes vs. frequency

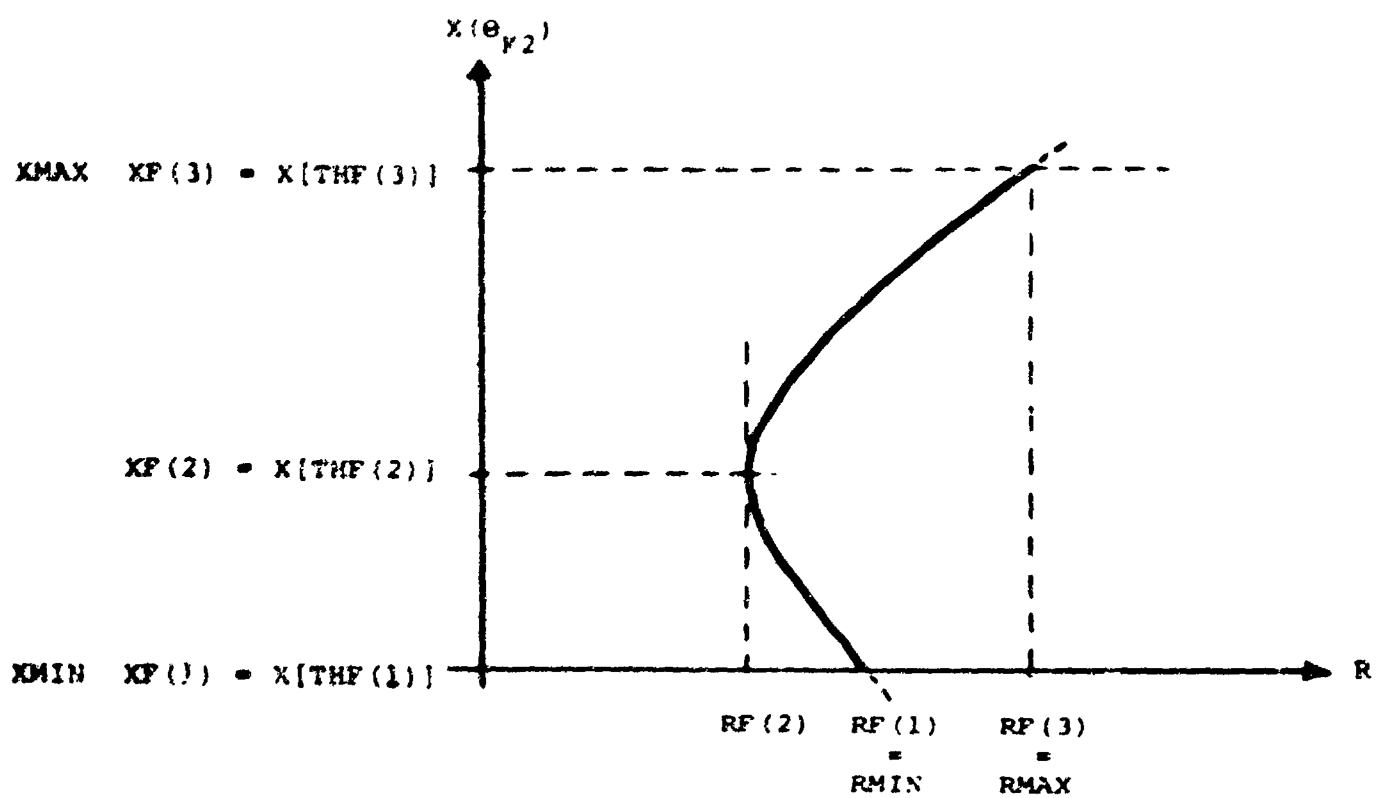
COMMON OUTPUTS

/FITS/	THF	Array (3) of angles of fit of R vs. θ for smooth caustic, radians
	RF	Array (3) of ranges of fit, feet
	A	Array (3) of coefficients of fit
	XMIN	Minimum value of argument of fit
	XMAX	Maximum value of argument of fit
	RMIN	Range of minimum-angle ray in family
	RMAX	Range of maximum-angle ray in family
	RANMIN	Minimum range at which intensities result
/CUSPCM/	RCUSP	Range of cusp, feet
	BCUSP	Cusp parameter beta

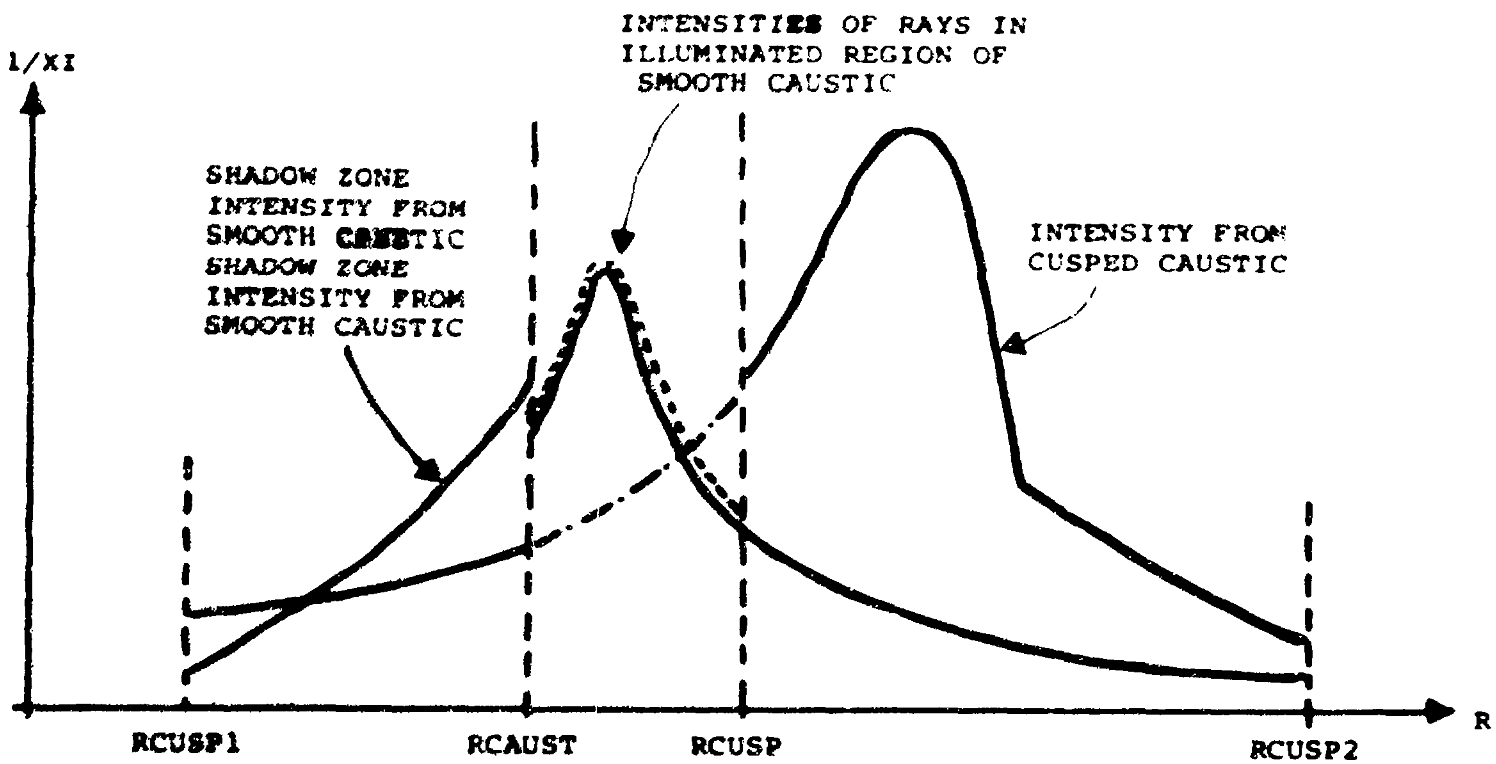


CUSP -- Fit OF R vs. TH

1 , 2 etc. refer to path subscript values in R (angle, path) array

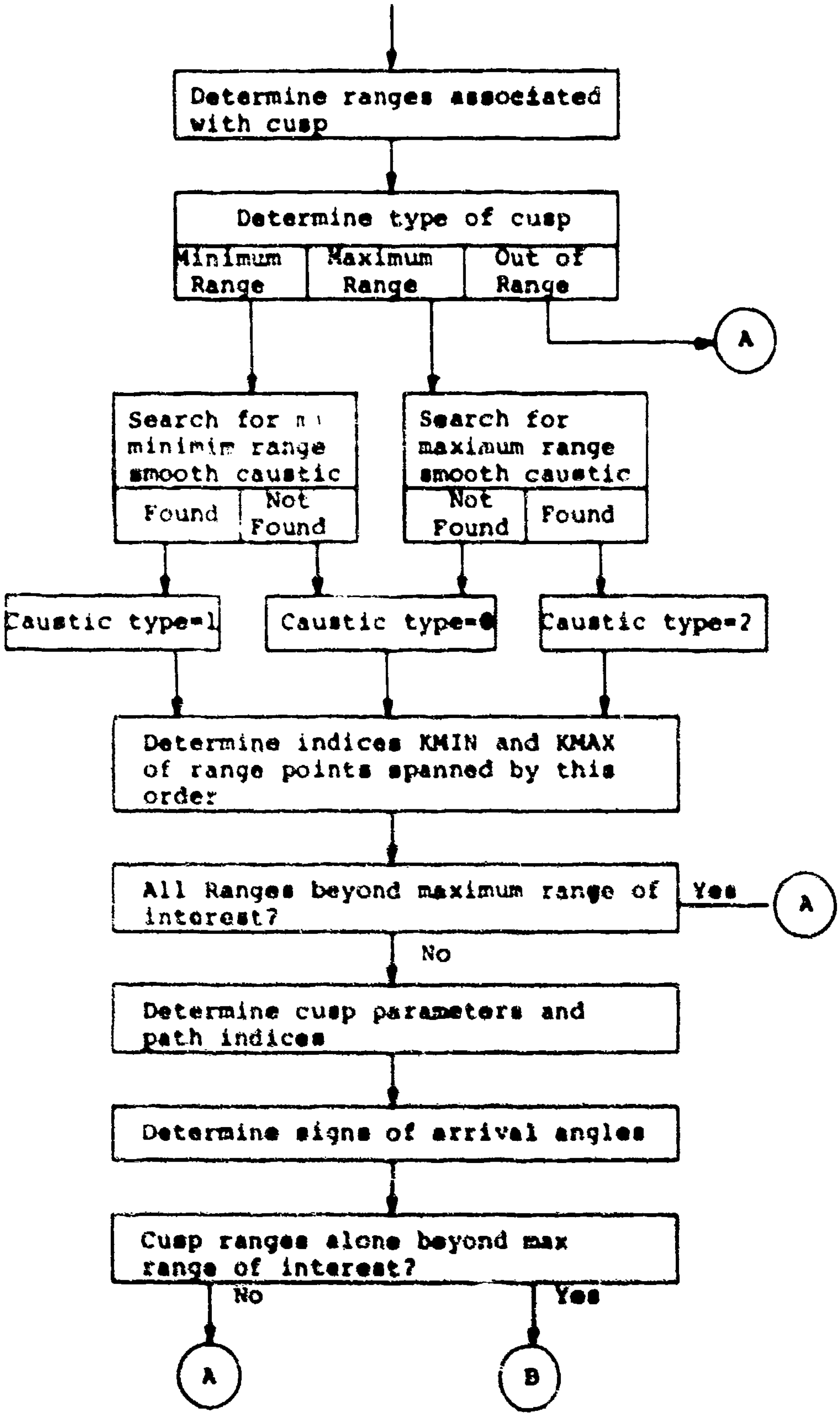


CUSP - Parameters Of Fit Of Smooth Caustic

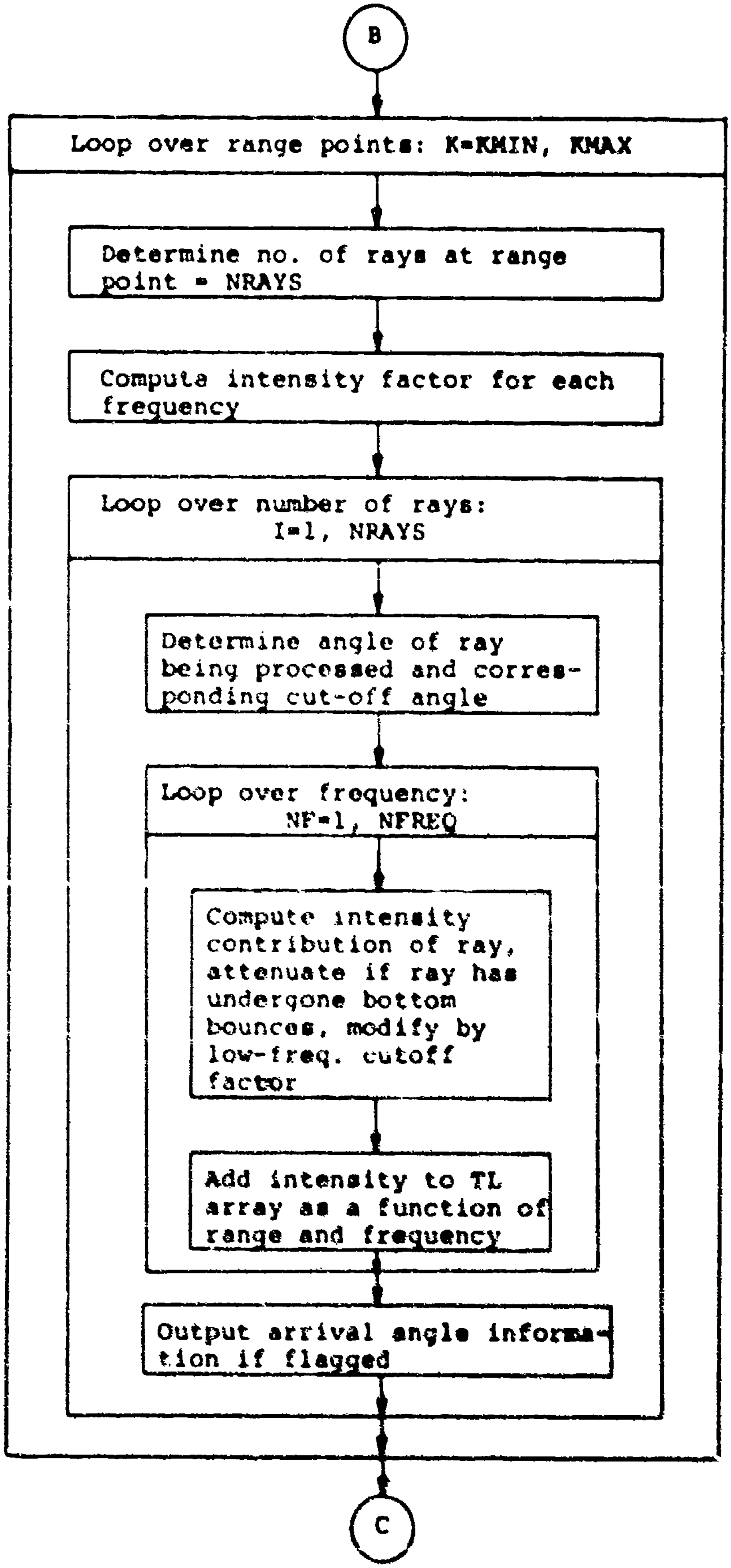


CUSP - Selection of Intensities in Region of CUSP With A Smooth Caustic

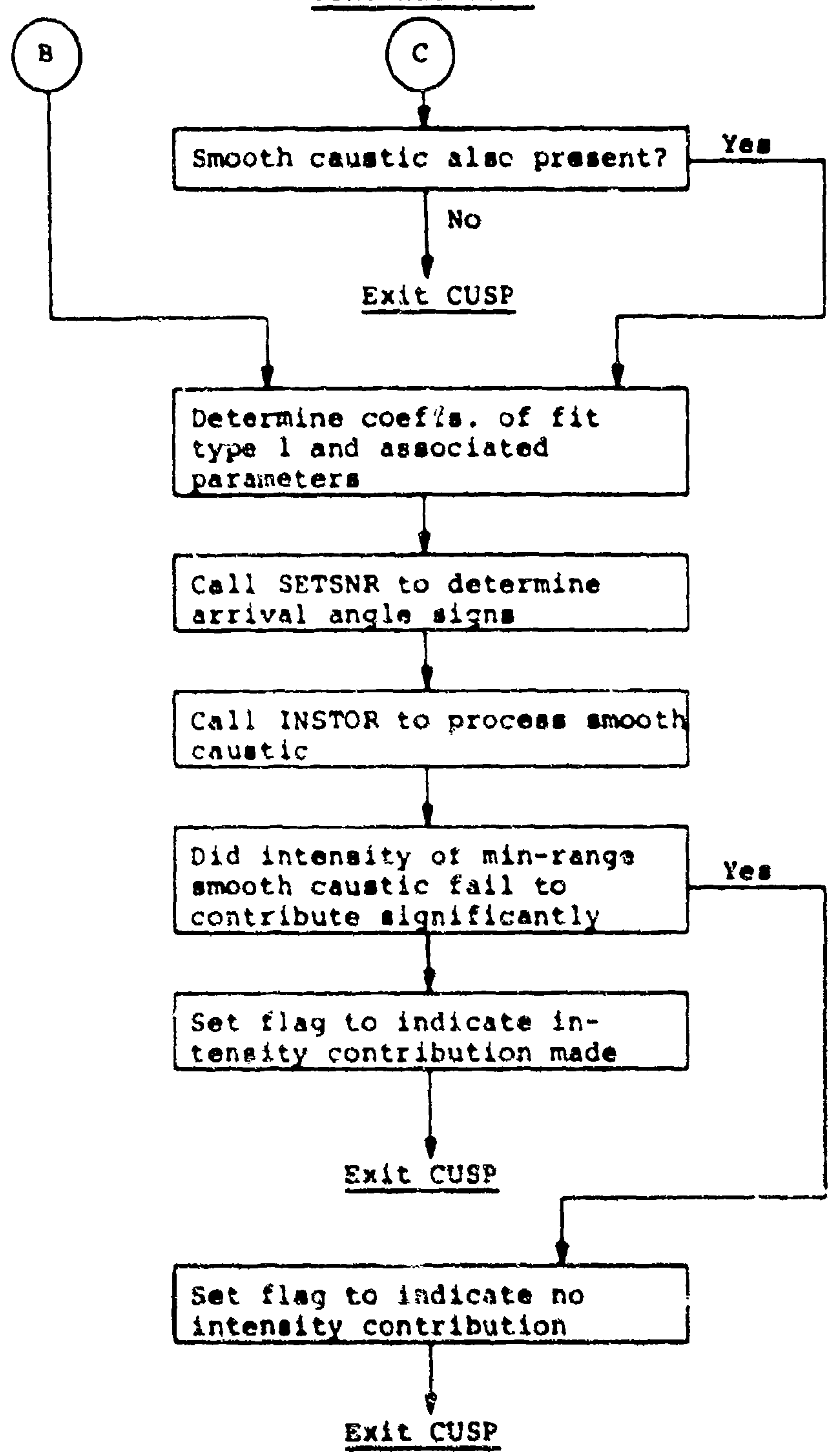
Begin CUSP


Determine ranges associated with cusp
Determine type of cusp
Minimum Range
Maximum Range
Out of Range
A
Search for minimum range smooth caustic
Found
Not Found
Search for maximum range smooth caustic
Not Found
Found
Caustic type=1
Caustic type=0
Caustic type=2
Determine indices KMIN and KMAX of range points spanned by this order
All Ranges beyond maximum range of interest?
Yes
A
No
Determine cusp parameters and path indices
Determine signs of arrival angles
Cusp ranges alone beyond max range of interest?
No
Yes
A
B

Continue CUSP



Continue CUSP



SUBROUTINE HFCHTL

HFCHTL is called by FACTTL to calculate the intensities for other than direct and bottom-surface-reflected paths when the half-channel indicator has been set on input (index of mixing layer at bottom depth: IML = NPTS). The routine is strictly applicable only for three source/receiver depth combinations (60/60 feet, 200/300 feet, 200/60 feet) and frequencies (50, 300, 850, 1700 Hz). The computed intensities are proportional to 1/Range; the constant of proportionality is initially expressed as a transmission loss (dB re 1 foot) in the form:

$$TL = A - B \cdot \log (D/1000)$$

where D is the half-channel depth in feet.

The coefficients A and B are each chosen from a separate 3x4 array as a function of source/receiver depth combination and of frequency. The coefficients in these arrays were themselves computed by FACT, using a temporary correction set to bypass the contributions to transmission loss arising from the direct and bottom-surface-reflecting paths. These FACT runs were made using a simple pressure-gradient profile (Δvelocity/Δdepth = .018 sec^{-1}) to half-channel depths of 1000 and 18,000 feet.

PARAMETER INPUTS

NR No. of range points, ≤ 250

HFCHTL (Cont'd)

NFREQ	No. of frequencies, ≤ 6
YS	Source depth, feet
YR	Receiver depth, feet
D	Depth of half-channel, feet
FREQB	Array (6) of frequencies, Hz
RANGE	Array (250) of range points, feet

PARAMETER OUTPUTS

TL	Array (250,6) to which intensities are added as a function of range and frequency.

SUBROUTINE QUAD

QUAD is called from INSTOR to solve the quadratic equation expressing R as a function of X(θ), in order to find the value(s) of X(θ) (and thus the value(s) of θ), if any, at the range point being processed in INSTOR. The roots are constrained to lie between XMIN = $X(\theta_{Min})$ and XMAX = $X(\theta_{Max})$. QUAD returns the number of roots = 0, 1 or 2, and the corresponding (ordered) values of X(θ). See diagram page 4-83.

The notation in QUAD

Y = A(1) + A(2)*X + A(3)*X**2

corresponds to

R = A(1) + A(2)*X(θ) + A(3)*X(θ)**2

in INSTOR.

PARAMETER INPUTS

A	Array (3) of coefficients of fit
XMIN	Minimum value allowable for X
XMAX	Maximum value allowable for X
Y	The range for which X values are desired

PARAMETER OUTPUTS

X	Array (2) of solutions of equation
IFLAG	No. of X values returned (0, 1 or 2)

FUNCTION SPEED

SPEED is called from INSERT to linearly interpolate in the sound velocity profile to determine the velocity corresponding to a source or receiver depth which has not been explicitly included as a point on the input profile. The results are unpredictable if this depth is less than the minimum profile depth; the last segment of the profile is linearly extrapolated for a depth greater than the maximum profile depth.

PARAMETER INPUT

YP Depth at which velocity is to be determined, feet

COMMON INPUT

/VELOCX/	NPTS	No. of points on profile
	Y	Array (60) of profile depths, feet
	C	Array (60) of profile velocities, ft/sec

FUNCTION OUTPUT

SPEED Interpolated value of velocity at depth YP, ft/sec

FUNCTION SETSNR

SETSNR is called from FACTTL and CUSP to determine the sign(s) of the arrival angle(s) at the depth at which arrival information is being determined. It returns the sign(s) of the angle of the ray(s) corresponding to the path of interest, which may be multiple, according to the coherency option in effect. If KRC = 1, the sign of the angle(s) at depth K1 is returned; if KRC = 2, the sign of the angle(s) at depth K2 is returned. A value of 0. is returned to indicate that both up- and down-going rays (signs = +1. and -1.) are present.

PARAMETER INPUTS

ICOH	Coherency option in effect - 0,1,2 or 3
KRC	Flag indicating arrival depth
K1	Index of source depth
K2	Index of receiver depth
KP	Index of path being processed

FUNCTION OUTPUT

SETSNR	Sign(s) of arrival angles: +1., -1., 0. See below for values returned as a function of input parameters.

KRC = 0: 0.

KRC = 1:

ICOH	KP 1	KP 2	KP 3	KP 4
0	1.	-1.	1.	-1.
1	0.	0.	0.	0.
2	1.	-1.	1.	-1.
3	0.	0.	0.	0.

KRC = 2:

(K1 Deeper Than K2)

ICOH	KP 1	KP 2	KP 3	KP 4
0	-1.	-1.	+1.	+1.
1	-1.	-1.	+1.	+1.
2	0.	0.	0.	0.
3	0.	0.	0.	0.

KRC = 2:

(K2 Deeper Than K1)

ICOH	KP 1	KP 2	KP 3	KP 4
0	+1.	+1.	-1.	-1.
1	+1.	+1.	-1.	-1.
2	0.	0.	0.	0.
3	0.	0.	0.	0.

SETSNR - Function Value Returned

FUNCTION FAIRY

FAIRY is called by INSTOR as a step in calculating the intensities which exist in the neighborhood of a smooth caustic. The function is related to the Airy function (for real arguments) as follows:

$$\text{FAIRY}(X) = \left[\frac{Ai(0)}{Ai(-X)}\right]^2 \qquad -1.77 \leq -X \leq 4.0$$

$$= \left[\frac{Ai(0)}{Ai(-4)}\right] \qquad X < -4.0$$

$$= .792 \cdot (X)^{1/2} \qquad X > 1.77$$

The function is approximated over the primary range of interest by 10.**CX, where CX is interpolated from tabulated values of C(I) vs. I; these values are:

$$C(I) = 2\log_{10}\left[\frac{Ai(0)}{Ai(\frac{I-11}{5})}\right] \qquad I = 1(1)31$$

This range of I corresponds to -X ranging from -2. to +4. at intervals of 0.2.

PARAMETER INPUT

X Argument of function

FUNCTION OUTPUT

FAIRY Functional value corresponding to X

FUNCTION XICUSP

XICUSP is called by CUSP and INSTOR as a step in calculating the intensities which exist in the neighborhood of a cusped caustic. The function computes the vertical spreading near the cusp, returning the single-path value assuming three equal-amplitude paths in the interference (three-ray) region and one path in the one-ray region. The calculation is three-step:

1) $X = \left[\frac{\beta \cdot W}{C}\right]^{1/2}$

where:

β = Cusp parameter

W = Radian frequency

C = Cusp sound velocity

2) $Y = f[\pm(R-R_C) \cdot X]$

where:

R = Range of interest, feet

R_C = Range of cusp, feet

f is calculated by call to function FE2B. The sign of the argument is positive in the one-ray region, negative in the three-ray region.

3) $XICUSP = \pi/(X \cdot Y)$

PARAMETER INPUTS

IR Flag indicating one- or three-ray region

RAN Range of interest, feet

FREQ Frequency, Hz

XICUSP (Cont'd)

FUNCTION OUTPUT

XICUSP	Functional value of spreading

FUNCTION PE2B

PE2B is called from XICUSP to calculate the Pearcey-function component of the expression for vertical spreading in the vicinity of a cusp. The function is related to the Pearcey function as follows:

$$
\begin{aligned}
PE2B(y) &= \pi/-y & \quad & y \leq -3.5 \\
&= \frac{Pe(y)}{3} & & -3.5 < y \leq 0 \\
&= Pe(y) & & 0. < y < 2. \\
&= \pi/y & & y \geq 2.0
\end{aligned}
$$

The function Pe(y) is approximated over the primary range of interest by P**2, where P is interpolated from tabulated values of PT(I) vs. I; I = 1(1)23. This range of I corresponds to y ranging from -3.5 to 2.0 at intervals of 0.25.

PARAMETER INPUT

Y Argument of function

FUNCTION OUTPUT

PE2B Functional value corresponding to y

FUNCTION THBOT

THBOT is called by INSTOR and CUSP to determine the ray angle at the bottom as a function of the ray angle at the receiver depth. This angle is determined from linear interpolation in the values of bottom angle vs. receiver ray angle as previously tabulated by routine TABTH2.

PARAMETER INPUTS

TH2	Ray angle at receiver depth (K2)

COMMON INPUTS

/TH2TAB/	TH2MIN	Minimum ray angle at receiver depth
	FACTOR	Reciprocal of increment of TH2T values
	TH2T	Array (21) of ray angles at receiver depth
	THBT	Array (21) of ray angles at the bottom
	RATIO	Array (20) of ratio of increments of TH2T to increment of THBT

FUNCTION OUTPUT

THBOT	Interpolated value of bottom angle

FUNCTION BOTTOM

BOTTOM is called from INSTOR and CUSP to calculate the intensity attenuation occurring along bottom-bounce ray paths. The attenuation is returned as a value between 0 and 1. Currently, BOTTOM returns a 1 (no attenuation) if the input bottom type is 0, and calls upon FNWC routine BTMLOS for bottom types 1-9. This routine may be replaced or restructured according to the desires of the FACT user.

PARAMETER INPUTS

NBOT	No. of bottom bounces
IBTYP	Bottom type, 0-9
THB	Ray angle at bottom, radians
FREQ	Frequency, Hz

FUNCTION OUTPUTS

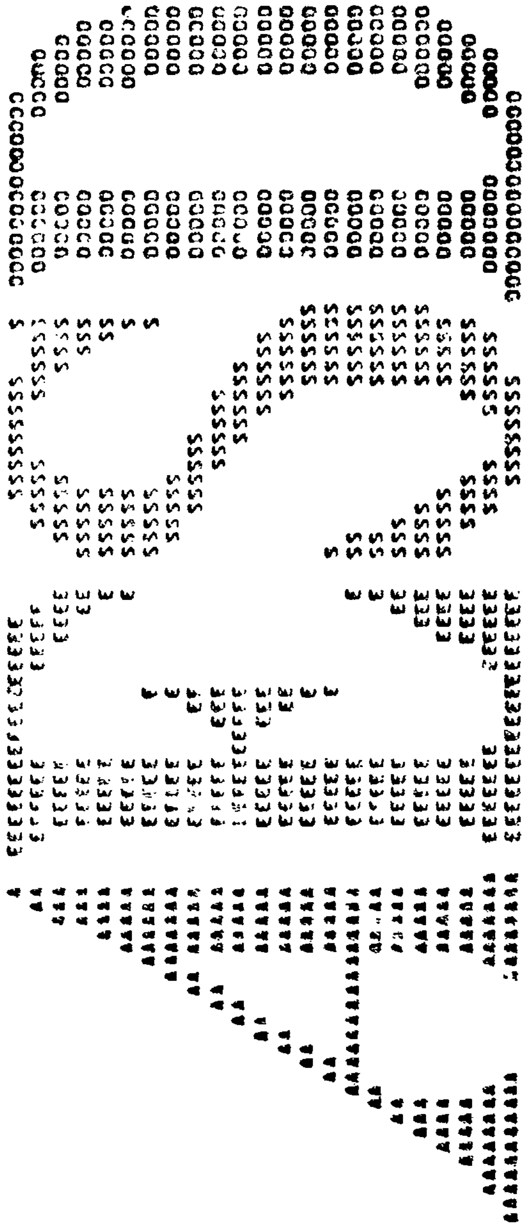
BOTTOM	Bottom attenuation

5. THE FACT HANDOUT

The following pages contain a reproduction of the AESD FACT Handout, a computer-maintained document which is an integral part of the FACT Package. The various sections are as follows:

- A description of the physical basis of the FACT Model;
- A description of the computer program flow;
- A description of the FACT Package Program Library;
- A description of the input card formats accepted by the TLOSS program;
- A description of the input deck structure;
- A listing of a sample set of input data cards;
- The outputs resulting from this input deck;
- The listing produced by a CDC 6600 FORTRAN compilation of FACT.

Of the last section, only the listing of the program TLOSS is included in this report.



FAST ASYMPTOTIC COHERENT TRANSMISSION (FACT) MODEL

DEVELOPED BY

ACOUSTIC ENVIRONMENTAL SUPPORT DETACHMENT

OFFICE OF NAVAL RESEARCH

1 APRIL 1973

THE FACT MODEL IS A RAY ACOUSTIC MODEL WHICH UTILIZES HIGHER ORDER THEORY FOR THE SOLUTION IN THOSE AREAS IN WHICH THE ASSUMPTIONS OF RAY ACOUSTICS ARE LIMITING. THE PRINCIPAL IMPROVEMENTS OF THE FACT PROGRAM ARE AS FOLLOWS--

THE GEOMETRIC INTENSITIES COMPUTED BY THE CLASSICAL EXPRESSIONS OF RAY ACOUSTICS ARE DISCARDED AT CAUSTICS WHERE THEY PREDICT INFINITE INTENSITY. RATHER, THE FIELD NEAR THE CAUSTIC IS EVALUATED USING THE APPROPRIATE ASYMPTOTIC EXPRESSIONS FOR THE PARTICULAR TYPE OF CAUSTIC-

1. SMOOTH CAUSTICS (2-RAY SYSTEMS) - BREKHOVSKIKH'S EXPRESSIONS.
2. CUSPED CAUSTICS (3-RAY SYSTEMS) FOR SOURCE AND RECEIVER AT THE SAME DEPTH - LUDWIG'S EXPRESSIONS.
3. COMBINED SMOOTH AND CUSPED CAUSTICS (4-RAY SYSTEMS). THE RMS SUM OF THE SMOOTH AND CUSPED-CAUSTIC FIELDS.

CAUSTIC FIELDS ARE EXTENDED INTO THE SHADOW ZONE TO THE RANGE OF THE CUSP WHERE THE SMOOTH CAUSTIC ORIGINATED.

THE TOTAL INTENSITY AT ANY ONE RANGE POINT IS COMPUTED BY A "SEMI-COHERENT" ADDITION OF ARRIVALS. FOR SHALLOW SOURCES AND/OR RECEIVERS THE PATHS WITHIN AN ARRIVAL ORDER WHICH DIFFER ONLY BY A SURFACE REFLECTION AT THE SOURCE (AND RECEIVER) HAVE PREDICTABLE PHASES RELATIVE TO ONE ANOTHER. PHASE DIFFERENCES BETWEEN DIFFERENT FAMILIES OF ARRIVAL ORDERS ARE LESS PREDICTABLE. THE "SEMI-COHERENT" SUMMATION REFERS TO THE COHERENT OR PHASED SUMMATION OF THE FIRST SET OF PATHS FOLLOWED BY THE INCOHERENT OR POWER SUMMATION OF THE RESULTING SETS. AS THE RATE IN THE OSCILLATIONS OF A PARTICULAR COHERENT SUMMATION INCREASES THE RANGE GRID MAY BECOME TOO COARSE TO ADEQUATELY SAMPLE THE OSCILLATIONS. WHEN THIS OCCURS THE SUMMATION IS PERFORMED WITH AN EFFECTIVELY REDUCED COHERENCE UNTIL FOR VERY COARSE GRIDS ALL PATHS ARE SUMMED INCOHERENTLY.

AXIS-TO-AXIS TRANSMISSION IS TREATED IN THE FOLLOWING WAY. THE PERIOD OF THE AXIAL RAY IS COMPUTED FOR THE SMOOTH PROFILE CORRESPONDING TO THE LINEARLY SEGMENTED PROFILE. THE RAY WITH THE SAME PERIOD WHEN TRACED IN THE LINEARLY SEGMENTED PROFILE IS FOUND AND THE DEPTHS OF ITS HORIZONTAL TURNING POINTS ARE DETERMINED. IF THE SOURCE AND RECEIVER ARE BETWEEN THESE DEPTHS, THEY ARE BOTH MOVED TO THE NEARER DEPTH. THE NET EFFECT OF THIS MOVE IS TO PRODUCE A CUSPED CAUSTIC AT THE RANGE OF THE CUSP WHICH WOULD OCCUR FOR THE AXIAL-RAY FAMILY IN THE EQUIVALENT SMOOTH PROFILE.

A WKB PHASE-INTEGRAL TECHNIQUE IS USED TO REDUCE THE INTENSITY (ON A FREQUENCY DEPENDENT BASIS) OF THE RAYS SHALLOWER THAN THE RAY-EQUIVALENT OF THE FIRST NORMAL MODE. THIS SIMULATES LOW-FREQUENCY CUT-OFF EFFECTS ON RAYS WHICH CYCLE WITH VERTICAL AMPLITUDES WHICH ARE SMALL IN TERMS OF WAVELENGTHS.

A SHALLOW WATER MODEL IS INCLUDED WHICH MAY BE EXERCISED FOR WATER DEPTHS OF LESS THAN 1000 FEET, AND FREQUENCY/BOTTOM CLASS COMBINATIONS WHERE RAYS STRIKING THE BOTTOM AT LESS THAN CRITICAL SUFFER NO REFLECTION LOSS. THE RESULTING TRANSMISSION LOSS CURVE IS A SMOOTHED APPROXIMATION TO THE CURVE GENERATED IN THE FACT MODEL AND REQUIRES CONSIDERABLY LESS COMPUTATION TIME. FOR ASRAP PURPOSES THE SHALLOW WATER MODEL IS ALWAYS USED WHERE APPROPRIATE. FOR THE GENERAL USER IT IS OPTIONAL.

A HALF CHANNEL MODEL HAS ALSO BEEN INCLUDED SPECIFICALLY FOR ASRAP PURPOSES. FOR THE PARTICULAR SOURCE DEPTHS AND FREQUENCIES USED IN ASRAP HALF-CHANNEL CASES THE INTENSITY DUE TO RSR PATHS IS APPROXIMATED BY A CURVE OF THE FORM OF

TL = A + 10 * LOG (R)

WHERE A IS A FUNCTION OF THE SOURCE AND RECEIVER DEPTHS, THE FREQUENCY, AND THE BOTTOM DEPTH. AGAIN THIS CURVE APPROXIMATES THE NORMAL FACT RESULT, HOWEVER, TAKES CONSIDERABLY LESS COMPUTER TIME. FOR ASRAP THIS IS ALWAYS USED WHERE APPROPRIATE. FOR GENERAL USERS IT WILL BE INVOKED WHEN THE MIXED LAYER DEPTH IS SET TO THE BOTTOM, HOWEVER UNLESS THE SOURCE AND RECEIVER DEPTHS AND FREQUENCIES CORRESPOND TO ASRAP CASES IT SHOULD BE AVOIDED. FINALLY,THE BASIC TRANSMISION LOSS PROGRAM (EXCLUDING THE SHALLOW-WATER AND HALF CHANNEL APPROXIMATIONS) MAY BE USED TO OBTAIN ARRIVAL STRUCTURE AS FOLLOWS. FOR EACH RAY THROUGH EACH RANGE POINT A RECORD IS WRITTEN ON DISC (OR TAPE) CONTAINING -

RANGE,ANGLE,(TL(I),I=1,NFREQ) (FORMAT 8F10.3)

WHICH MAY BE USED FOR LATER COMPUTATIONS. THE ANGLE (RANGE) CURVE IS ALSO PLOTTED (ON THE LINE PRINTER).

FACT MODEL PROGRAM FLOW

THIS SECTION DESCRIBES THE PROGRAM FLOW IN THE TRANSMISSION LOSS MODULE (SUBROUTINE FACTTL). THE OTHER DECKS, TLOSS, ETC. ARE MERELY DRIVER PROGRAMS TO CALL FACTTL.

FACTTL -

- INITIALIZATION OF VARIABLES AND ARRAYS
- CALL INSERT
  - MAKES SPHERICAL EARTH CORRECTIONS ON PROFILE AND SOURCE AND RECEIVER
  - COMPUTES MIXED LAYER AND THERMOCLINE GRADIENTS FOR SURFACE DUCT CALCULATION (IF APPLICABLE)
  - CALL AXIS
    - COMPUTES PERIOD OF ZERO-DEGREE RAY ALONG AXIS OF SMOOTHED EQUIVALENT PROFILE AND MOVES SOURCE AND RECEIVER (IF NECESSARY) TO SIMULATE AXIS-TO-AXIS TRANSMISSION.
    - COMPUTES LIMITING ANGLE FOR SUBSEQUENT PHASE INTEGRAL CALCULATIONS.
    - INSERTS SOURCE AND RECEIVER INTO PROFILE MOVING THEM SLIGHTLY OR CHANGING SOUND SPEEDS SLIGHTLY TO PREVENT THEM FROM HAVING THE SAME SOUND SPEED.
    - COMPUTES INFORMATION NEEDED FOR SUBSEQUENT LOCATION OF THE CUSPS FROM WHICH SMOOTH CAUSTICS IN THE FIRST FAMILY OF RAYS ORIGINATE.
    - COMPUTATION OF FREQUENCY-DEPENDENT FACTOR FOR COHERENCE, ABSORPTION, AND SURFACE DUCTS.
- CALL TABTH2
  - TABULATES THE RAY ANGLE AT THE BOTTOM IN TERMS OF THE ANGLE AT EITHER THE SOURCE OR RECEIVER DEPTH (WHICHEVER HAS A HIGHER SOUND SPEED).
- CALL CRITA
  - COMPUTES WKB PHASE FACTORS FOR LOW-FREQUENCY CUT-OFF EFFECTS.
- CALL ANGSCH
  - DETERMINES RAYS TO BE TRACED AND DEFINES RAY FAMILIES WITHIN WHICH INTERPOLATIONS ARE VALID IN A SMOOTHED ANGLE VERSUS RANGE CURVE.

- LOOP ON EACH FAMILY
  - CALL RANGER FOR EACH RAY IN FAMILY
    - COMPUTES PERIOD AND RANGES OF FIRST AND SECOND ARRIVALS OF UPGOING RAY.
  - COMPUTE SEMI-COHERENT PHASE FACTORS FOR THIS FAMILY.
  - GROUP ARRIVALS FOR COHERENT COMBINATION OR IF CLOSE ENOUGH IN RANGE TO BE CONSIDERED IDENTICAL. THE NUMBER OF ARRIVALS IN A SINGLE ORDER MAY THEN BE REDUCED FROM THE USUAL FOUR TO TWO OR ONE WITH CORRESPONDING CHANGES IN AMPLITUDE.
  - PROCESS EACH REMAINING ARRIVAL IN SUCCESSIVE ARRIVAL ORDERS UNTIL THE FAMILY (AND ITS CAUSTIC SHADOW ZONE FIELDS) HAS EXCEEDED THE MAXIMUM RANGE OF INTEREST.
  - FOR STEEPEST RAY FAMILY (BOTTOM-REFLECTED SURFACE-REFLECTED) CALL FITBOT
    - COMPUTES PARAMETERS OF FIVE COEFFICIENT FIT TO R(THETA) USING MINIMUM RAY, RAY AT CRITICAL ANGLE OF LOW FREQUENCY BOTTOM-REFLECTION COEFFICIENT, AND IMPLICITELY 90-DEGREE RAY.
  - FOR SHALLOWER FAMILIES CALL FINDFT
    - FITS A QUADRATIC IN EITHER TAN(THETA) OF SQRT (THETA-THETAMIN) FOR R(THETA) THROUGH BOUNDING ANGLES OF FAMILY AND MIN (OR MAX) RANGE POINT IN FAMILY .
  - CALL INSTOR IF FAMILY DOES NOT CONTAIN CUSPED CAUSTICS
    - COMPUTES THE INTENSITY CONTRIBUTION FROM THE FAMILY AT EACH RANGE POINT.
    - CAUSTIC PARAMETERS AND FIELDS ARE COMPUTES AS WELL AS ALL SEMI-COHERENT FACTORS AND BOTTOM-REFLECTION LOSSES.
  - CALL CUSP FOR FAMILIES WITH CUSPED CAUSTICS
    - COMPUTES FAMILY PARAMETERS AND CUSPED CAUSTIC CORRECTIONS.
    - CALLS XICUSP TO COMPUTE CUSPED CAUSTIC FIELDS.
    - ADDS IN BOTTOM REFLECTION LOSS IF ANY.
    - FOR FOUR RAY SYSTEMS CALLS INSTOR TO COMPUTE SMOOTH CAUSTIC CONTRIBUTION.
- END PROCESSING OF A FAMILY, GO TO NEXT FAMILY

```
-  ADD IN HALF-CHANNEL NON BOTTOM-REFLECTED CONTRIBUTION
   (FOR ASRAP III HALF CHANNEL CASES ONLY))

-  ADD IN DUCTED CONTRIBUTION

-  CONVERT TO TLOSS(R,F)  (INCLUDING VOLUME ABSORPTION)

RETURN
```

```
THE FACT PACKAGE PROGRAM LIBRARY CONTAINS ALL FORTRAN
ROUTINES REQUIRED TO IMPLEMENT THE FACT ACOUSTIC MODEL.
THE PROGRAM LIBRARY COMPONENTS ARE AS FOLLOWS....

     MAINPROGRAM TLOSS-- READS CARD INPUTS, COMPUTES LOSSES THRU
                         SUBROUTINE CALLS, AND PRINTS AND/OR PLOTS
                         (ON THE LINE PRINTER) THE RESULTS.


     SUBROUTINE FACTTL--THE FACT RAY TRACING MODEL
     SUBROUTINE SHALTL--A SIMPLIFIED MODEL FOR SHALLOW WATER,
                        CALLED INSTEAD OF FACTTL BY AUTOTL
                        UNDER CERTAIN CONDITIONS.
     SUBROUTINE HFCHTL--A SIMPLIFIED HALF-CHANNEL MODEL, USED BY FACTTL
                        FOR ASRAP CASES.

THE FACT MODEL SUBROUTINE FACTTL REQUIRES
THE FOLLOWING ADDITIONAL ROUTINES....
     13 COMPUTATIONAL SUBROUTINES...     INSERT     AXIS      TABTH2
                                         CRITA      RAYT      ANGSCH
                                         RANGER     FITBOT    FINDFT
                                         FITQ       INSTOR    CUSP
                                         QUAD

     8 FUNCTIONAL SUBROUTINES....        SPEED      SETSHR    FAIRY
                                         XICUSP     PEZB      THBOT
                                         BOTTOM     BTMLOS
FOR INPUT AND OUTPUT PROGRAM TLOSS REQUIRES....
     3 INPUT-OUTPUT SUBROUTINES....      RDPROF     TLHEAD    PLOTTL


TO MAKE AN OBJECT PROGRAM FOR THE CARD INPUT PROGRAM TLOSS,
ALL COMPONENTS WITH THE EXCEPTION OF AUTOTL AND SHALTL SHOULD
BE COMPILED. THE RESULTING PROGRAM OCCUPIES APPROXIMATELY
44602 (OCTAL) WORDS ON THE CDC 6600.

IN THE (CDC 6600) FACT PACKAGE PROGRAM LIBRARY,
THE FOLLOWING CONVENTIONS HAVE BEEN FOLLOWED....

     EACH DECK IS A SINGLE PROGRAM, ROUTINE, OR FUNCTION.
     THE DECK NAME IS IDENTICAL TO THE ROUTINE NAME.
     ALL DECKS ARE SEQUENCED WITHOUT CORRECTIONS.
```

```
THE CARD INPUTS TO TLOSS ARE DETAILED IN THE COMMENTS WITHIN
THAT PROGRAM, AND REPEATED HERE FOR REFERENCE PURPOSES.

CARD               DATA                         FORMAT
----               ----                         ------
  1                TITLE                        8A10
        (EOF ENDS RUN)
  2                N,IL,IB,IM,IPL,IAP           6I5
 3A,B,...          Z(I),C(I)   (I=1,N)          8F10.2
                OR D(I),T(I),S(I)               3(F8.2,F6.2,F6.2)
  4                NR,DRNMI                     I5,5X,F10.2
  5                F(I)   (I=1,6)               6F10.2
  6                S,R,JC(I)   (I=1,6)          2F10.2,6I5
        (EOF ENDS RUN)
        (S.GE. 1OE6 GOES BACK TO READ CARD 1)

        FACTTL CALLED TO COMPUTE LOSSES
        LOSSES PRINTED AND/OR PLOTTED

        (GOES TO READ CARD 6)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

N   IS NO. OF PROFILE POINTS   2.LE.(ABS(N)).LE. 50

     *FOR A POSITIVE, PROFILE IS INPUT DIRECTLY IN DEPTH,
      VELOCITY PAIRS, 4/CARD. A VELOCITY .LT. 3000 IS USED AS AN
      INDICATOR OF METRIC INPUT (M,M PER S) BOTH DEPTHS + VELOCITIES
      ARE CONVERTED TO ENGLISH UNITS (FT,FT PER SEC).

     *FOR A NEGATIVE, PROFILE IS INPUT AS DEPTH, TEMP.,
      SALINITY TRIPLETS, 3/CARD. METRIC UNITS ARE ASSUMED (M,CENT,PPT).
      WILSONS FORMULA IS USED TO COMPUTE VELOCITIES. DEPTHS +
      VELOCITIES ARE THEN CONVERTED TO ENGLISH UNITS.

     *THE INPUT PROFILE IS ALWAYS PRINTED, IF CALCULATIONS +
      CONVERSIONS ARE REQUIRED, THE RESULTING VALUES ARE ALSO PRINTED.

     *THE BOTTOM DEPTH IS ALWAYS Z(N)


IL  IS THE INDEX OF THE MIXED LAYER DEPTH IN THE INPUT PROFILE (SEPARAT
     COMPUTATIONS ARE THEN PERFORMED FOR A SURFACE DUCT OF THIS
     DIMENSION AND NO RAYS ARE TRACED IN THE DUCT).  EITHER 1
     OR 0 CAN BE USED TO INDICATE THAT NO LAYER IS PRESENT.
     0 .LE. IL .LE. (ABS(N)).  IL = (ABS(N)) INDICATES THAT A
     HALF-CHANNEL CONDITION IS PRESENT AND THAT THE ROUTINE
     HFCHTL (NORMALLY USED ONLY FOR ASRAP) SHOULD BE USED.

IB  IS THE BOTTOM TYPE
     A NEGATIVE VALUE INDICATES THAT THE USER WILL SUPPLY A BOTTOM LOS
     FUNCTION, AND MODIFY FUNCTION BOTTOM TO CALL THE REPLACEMENT FOR
     THE DEFAULT FUNCTION BTMLOS.
     1-9 INDICATES FNWC BOTTOM LOSS FUNCTIONS
```

```
IW  IS THE WAVE HEIGHT IN FEET

IPL IS THE PRINT/PLOT INDICATOR
     0.. PRINT ONLY  (DB. LOSS VS. RANGE)
     1.. PAGE PLOT ONLY  (DB. LOSS VS. RANGE, 1 PAGE/FREQUENCY)
     2.. PRINT AND PLOT  (=0 PLUS 1)
    -1.. PAGE PLOT ONLY  (DB. LOSS VS. RANGE, ALL FREQS. ON SAME PLOT)
    -2.. PRINT AND PLOT  (=0 PLUS -1)

IAR  IS THE ARRIVAL CALCULATION INDICATOR
     0.. NO ARRIVALS
     1.. ARRIVAL ANGLES VS. RANGE CALCULATED AND PLOTTED

NR  IS THE NUMBER OF RANGE POINTS  1 .LE. NR .LE. 250

DR  IS THE INCREMENTAL (AND FIRST) RANGE IN N.MI.

F(I)  ARE THE FREQUENCIES - UP TO SIX - IN HERTZ.

S  IS THE SOURCE DEPTH IN FEET.

R  IS THE RECEIVER DEPTH IN FEET.

     *IF EITHER SOURCE OR RECEIVER DEPTH IS OUTSIDE THE PROFILE
      LIMITS (LESS THAN ZERO OR GREATER THAN Z(N)) THE
      SOURCE OR RECEIVER IS BOTTOMED.

JC(I)  ARE THE COHERENCY INDICATORS, AND CORRESPOND TO THE F(I)S 1-TO-1
       0 = SEMI-COHERENCE
       1 = INCOHERENCE
       2 = FULL COHERENCE

     *THE VALUES OF JC(I) ARE NORMALLY LEFT BLANK TO INDICATE THAT
      SEMI-COHERENCE IS TO BE USED FOR ALL FREQUENCIES.
```

A MACROSCOPIC LOOK AT DECK CONSTRUCTION

```
     /------------------------------------------------------------------------.
    /          EITHER 7-8-9 (END OF RECORD) OR VS .GE. 1E6 (NEW RUN)          .
   /              LAST CARD OF SOURCE-RECEIVER DEPTH DECK                     .
. /-----------------------------------------------------------------------------.
.//-----------------------------------------------------------------------------.
///-----------------------------------------------------------------------------.
///------------------------SOURCE AND RECEIVER DATA----------------------------.
///-----------------------------------------------------------------------------.
///-----------------------------------------------------------------------------.
///-----------------------------------------------------------------------------.
//  VS        TR     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
/                 TYPE 6 CARD--SOURCE AND RECEIVER DATA                        .
. /-----------------------------------------------------------------------------.
./  F1        F2        F3        F4        F5        F6     XXXXXXXXXXXXXXXXXXXX.
/                  TYPE 5 CARD--FREQUENCY INFORMATION                          .
. /-----------------------------------------------------------------------------.
./NR XXXXX  DRNMI    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
/                    TYPE 4 CARD--RANGE INFORMATION                            .
. /-----------------------------------------------------------------------------.
.//-----------------------------------------------------------------------------.
///-----------------------------------------------------------------------------.
///-------------------------------TYPE 3 CARDS---------------------------------.
///------------------------------DEPTH, VELOCITY--------------------------------.
///-------------------------------------OR--------------------------------------.
///----------------------DEPTH, TEMPERATURE, SALINITY--------------------------.
///-----------------------------------------------------------------------------.
///-----------------------------------------------------------------------------.
//Z(1)   T(1)  S(1)   Z(2)   T(2)  S(2)   Z(3)   T(3)  S(3) XXXXXXXXXXXXXXXXXXXX.
/                       TYPE 3 CARD--DATA SET                                  .
. /-----------------------------------------------------------------------------.
./NP   IL   IS   IW  IPL IAPXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
/                       TYPE 2 CARD--PARAMETERS                                .
. /-----------------------------------------------------------------------------.
./                          THIS IS THE TITLE                                  .
/                           TYPE 1 CARD--TITLE                                 .
.                                                                              .
.                                                                              .
.                                                                              .
.                                                                              .
.                                                                              .
.                                                                              .
.                                                                              .
.                                                                              .
.                                                                              .
.                                                                              .
.                                                                              .
.                                                                              .
................................................................................
```

OUTPUT DATA

THE RESULTS ARE PRESENTED IN ANY ONE OF FIVE OUTPUT FORMATS, DEPENDING ON THE PRINTOUT PARAMETER AS SPECIFIED ON THE TYPE 2 DATA CARD (INTEGER VARIABLE IPL).

THE FIRST DATA PRINTED IS THE TITLE CARD.

THE SECOND DATA PRINTED VERIFIES THE INPUT PARAMETERS AS FOLLOWS--

FIRST, NP, IL, IR, AND IW ARE PRINTED.
SECOND, ALL THE INPUT VALUES OF DEPTH AND VELOCITY OR TEMP.-SALINITY ARE PRINTED, PLUS ANY CONVERSIONS MADE.

THIRD, THE RANGE AND INCREMENT PARAMETERS BEING USED ARE PRINTED.

FOURTH, FACT PRINTS ALL FREQUENCIES BEING CONSIDERED AND THE COHERENCE OPTION--

0 = SCOH
1 = ICOH
2 = FCOH

UP TO THIS POINT, FACT HAS PRINTED ONLY DATA VALUES, TO ALLOW FOR VERIFICATION AND REFERENCE USE.

FACT WILL NOW PRINT COMPUTED RESULTS. THERE ARE TWO RESULT LISTINGS AVAILABLE-- (1) A TABLE OF TRANSMISSION LOSSES, AND (2) A GRAPH OF TRANSMISSION LOSSES (AND ARRIVAL STRUCTURE WHEN APPROPRIATE). WHETHER FACT WILL PRINT ONLY THE FIRST, ONLY THE SECOND, OR BOTH DEPENDS ON WHAT IPL PARAMETER WAS SPECIFIED ON THE TYPE 2 DATA CARD. THREE SAMPLE CASES ARE GIVEN BELOW TO ILLUSTRATE THE TYPES OF OUTPUT AND FOR REFERENCE PURPOSES IN CONVERTING FACT DECKS TO OTHER SYSTEMS/COMPUTERS.

DATA INPUT CARDS FOR SAMPLE FACT RUNS

```
COL.                                                                     COL.
1         11        21        31        41        51        61        71    80
---------------------------------------------------------------------------------
I         I         I         I         I         I         I         I     I

FACT SAMPLE RUN NO. 1 -- PRESSURE GRADIENT PROFILE. ARRIVAL STRUCTURE COMPUTED.
   2    0    4    0    -2    1
   0000.00   4776.00  12000.00   4992.00
  120          1.00
25.0       100.0
     60.00    1200.00
   1200.00    1200.00
9999999999
FACT SAMPLE RUN NO. 2 -- PROFILE IN MTRS AND MTRS/SEC WITH TWO POINT LAYER.
   10     2     4     0    -2     1
0.        1512.1    67.05     1532.8    76.20     1529.7    88.39     1525.8
118.87    1521.6    158.49    1518.2    164.58    1516.8    237.73    1509.9
259.07    1500.5    356.60    1499.7    390.12    1496.6    408.41    1496.0
466.32    1491.1    502.90    1488.7    542.52    1486.7    612.62    1483.5
643.10    1482.5    725.39    1481.1    851.40    1481.2    899.12    1481.5
999.70    1482.1    1200.85   1483.0    1398.96   1484.9    1600.12   1486.7
1798.23   1488.7    1999.39   1491.1    2499.24   1498.1    2999.09   1505.9
3453.22   1513.7    5325.47   1547.8
  120          1.00
100.0      300.0
    500.00  10800.00
    590.00    300.00
9999999999
FACT SAMPLE RUN NO. 3 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS.
  -16    0    2    1    2
 0000.00 12.36 35.11 0010.00 12.08 35.12 0020.00 11.74 35.13
 0038.00 11.11 35.15 0077.00 09.56 35.31 0125.00 08.98 35.27
 0153.00 08.71 35.25 0229.00 08.20 35.21 0379.00 07.89 35.15
 0529.00 07.42 35.14 0614.00 07.12 35.11 0814.00 05.82 35.04
 1021.00 04.55 34.98 1200.00 04.28 34.92 1400.00 03.99 34.89
 1551.00 03.76 34.89
  120          2.00
50.0       150.0
     60.00     600.00
    300.00    6000.00
```

THE RESULTING FACT OUTPUT APPEARS ON THE FOLLOWING PAGES

```
FACT SAMPLE RUN NO. 1 -- PRESSURE GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED.
    2    3    4    6
         0.00000     4776.00000
     12000.00000     4992.30000


   120            1.00
       25.00    180.00
```

TEST SAMPLE RUN NO. 1 -- PRESSURE GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED. 10.00.07 09/27/76

SOURCE DEPTH = 63.0 FT, RECEIVER DEPTH = 7230.8 FT

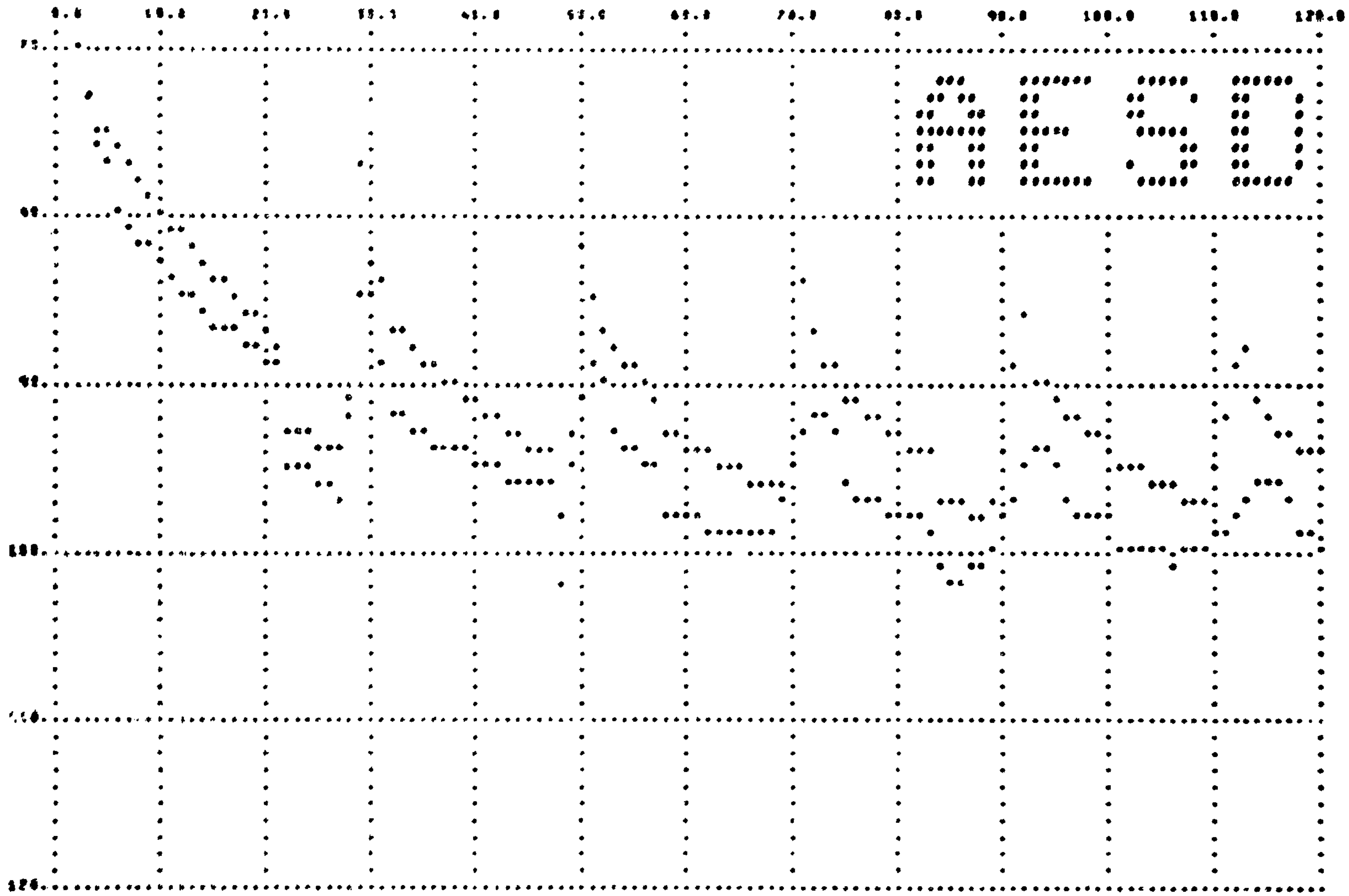
TRANSMISSION LOSS (DB RE 1 YD)

RANGE (N MI)	25 HZ, SCOM	100 HZ, SCOM
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

FACT SAMPLE RUN NO. 1 -- PRESSURE GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED. 10.58.22 09/27/76

SOURCE DEPTH = 61.0 FT. RECEIVER DEPTH = 7250.0 FT

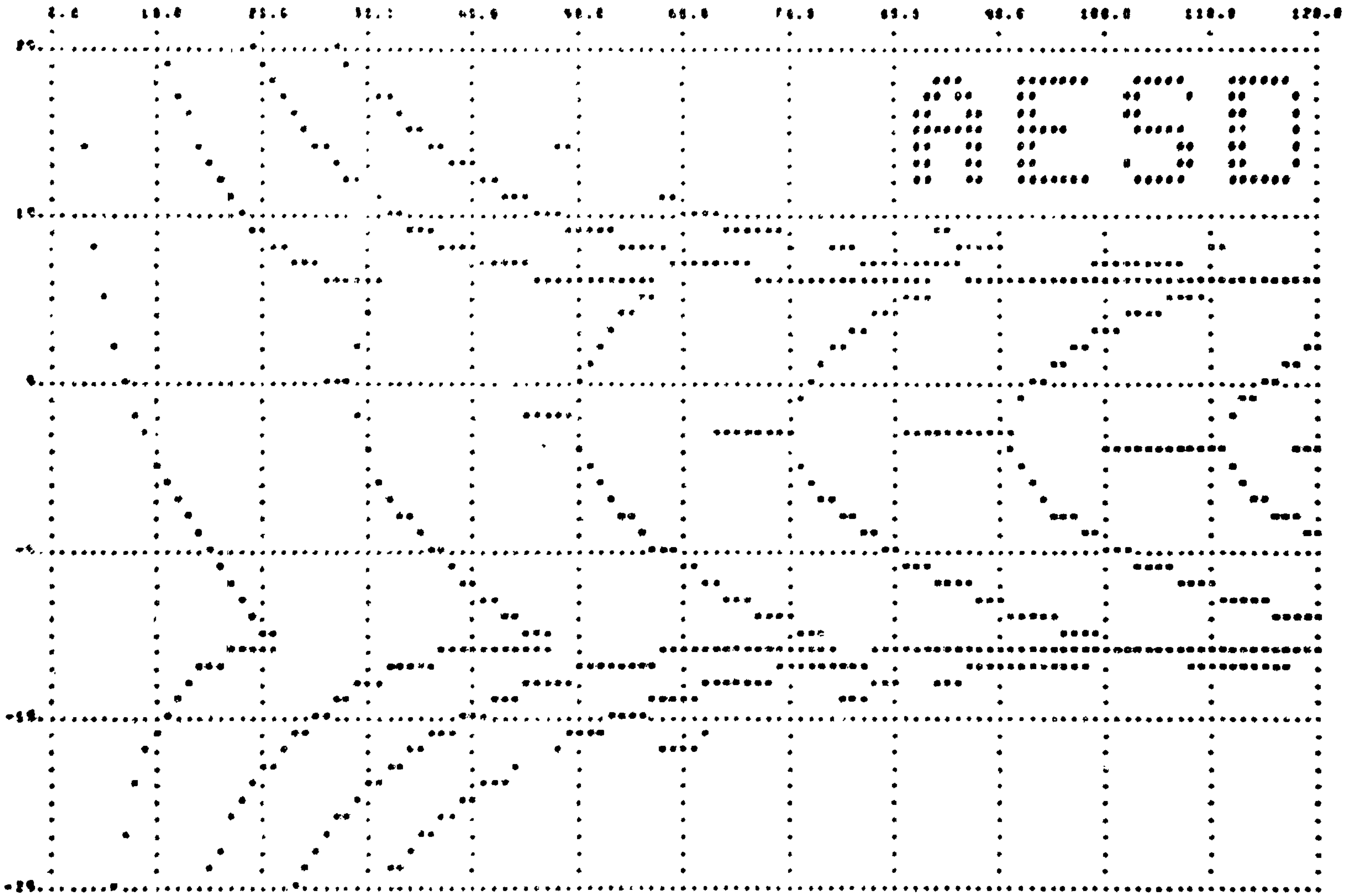
LEGEND-- 75 HZ, SCOM = * 100 HZ, SCOM = +



FACT SAMPLE RUN NO. 1 -- PRESSURE GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED. 10.58.29 09/27/74

SOURCE DEPTH = 61.0 FT, RECEIVER DEPTH = 7200.0 FT

ARRIVAL STRUCTURE -- ANGLE VS. RANGE



FAST SAMPLE RUN NO. 1 -- PRESSURE GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED.   10.50.29   10/27/76

SOURCE DEPTH = [illegible] FT. RECEIVER DEPTH = 7282.0 FT

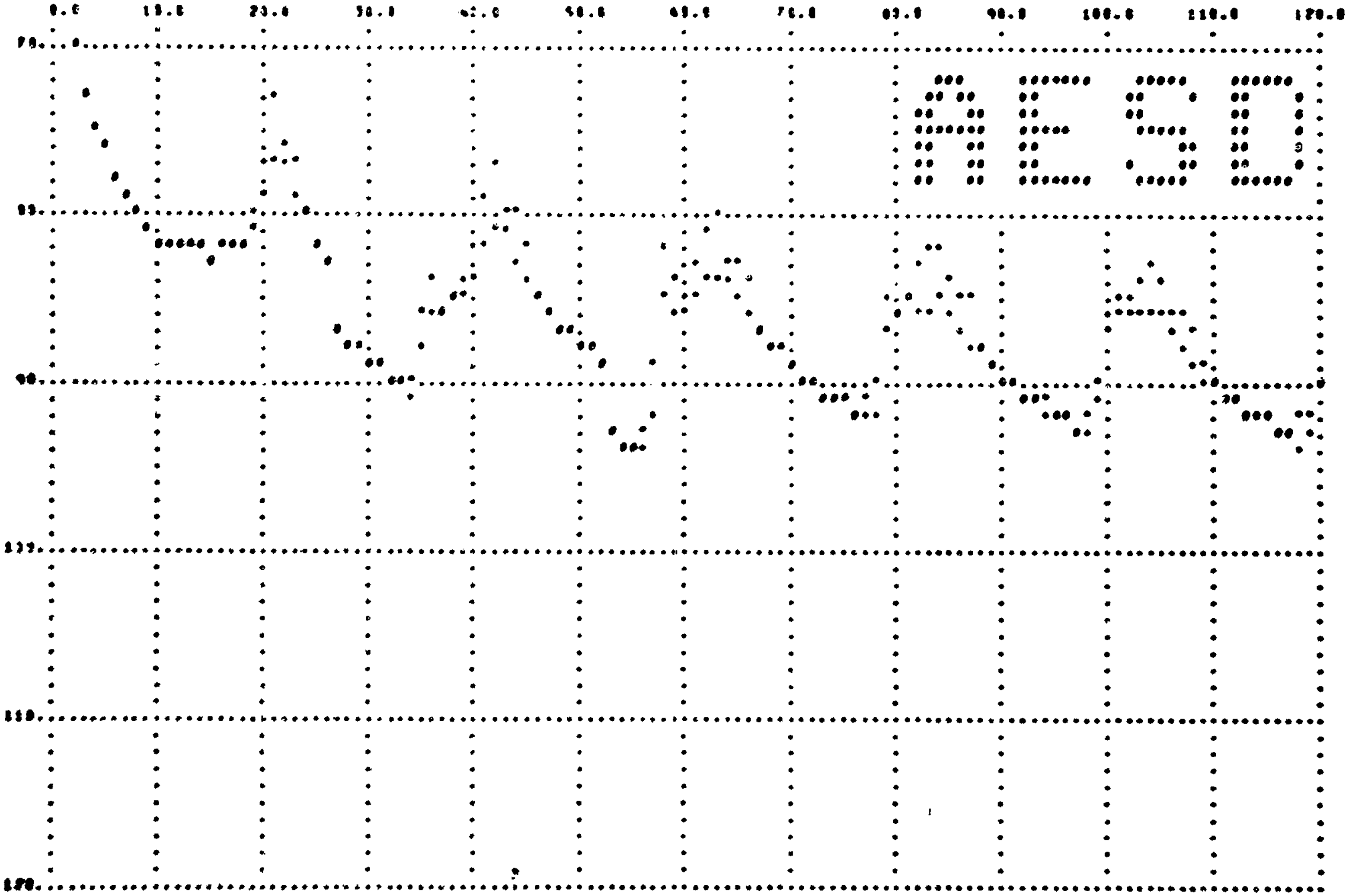
TRANSMISSION LOSS (DB RE 1 YD)

RANGE (N MI)	25 HZ. SCOM	133 HZ. SCOM
1.00	66.6	66.6
2.00	70.1	73.1
3.00	73.7	73.8
4.00	75.2	75.3
5.00	76.5	76.5
6.00	77.6	77.6
7.00	78.7	78.7
8.00	79.7	79.7
9.00	80.6	83.6
10.00	81.9	81.9
11.00	82.1	82.1
12.00	82.7	82.[illegible]
13.00	82.4	82.4
14.00	82.5	82.5
15.00	82.5	82.6
16.00	82.4	82.4
17.00	82.5	82.5
18.00	81.5	81.5
19.00	81.6	80.7
20.00	79.[illegible]	77.3
21.00	77.2	73.2
22.00	75.9	76.0
23.00	74.5	75.8
24.00	80.6	83.5
25.00	81.6	81.6
26.00	82.6	82.6
27.00	87.2	87.2
28.00	87.6	87.6
29.00	88.3	88.6
30.00	90.9	89.9
31.00	89.6	87.6
32.00	90.0	89.5
33.00	90.2	90.3
34.00	91.1	91.7
35.00	84.2	87.6
36.00	90.6	84.3
37.00	90.1	86.2
38.00	85.2	85.3
39.00	90.8	83.9
40.00	83.7	82.2
41.00	82.5	79.3
42.00	81.2	77.2
43.00	91.3	83.0
44.00	86.6	82.9
45.00	87.3	84.1
46.00	89.2	85.1
47.00	95.0	85.9
48.00	96.5	86.6
49.00	97.1	87.2
50.00	97.7	87.0
51.00	90.2	88.3
52.00	88.7	88.8
53.00	91.2	93.2
54.00	93.5	93.0
55.00	95.0	93.9
56.00	93.8	90.3
57.00	89.6	91.4

FACT SAMPLE RUN NO. 1 -- PRESSURE GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED. 10.58.40 09/27/76

SOURCE DEPTH = 7200.0 FT, RECEIVER DEPTH = 7233.0 FT

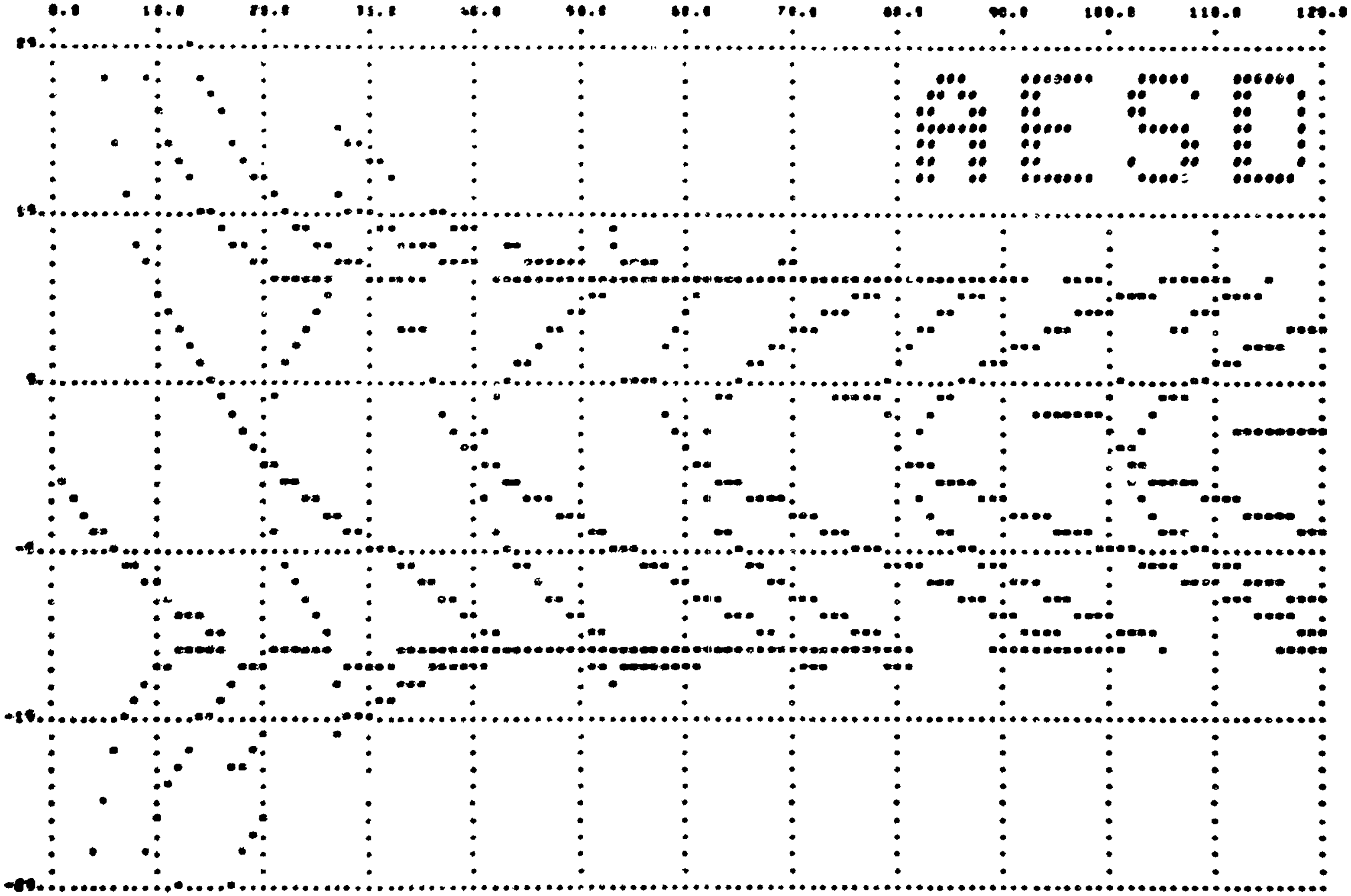
LEGEND-- 25 HZ, SCDM = * 125 HZ, SCDM = +



FACT SAMPLE RUN NO. 1 -- PRESSURE GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED.   10.50.50   09/27/76

SOURCE DEPTH = 7280.0 FT, RECEIVER DEPTH = 7299.4 FT

ARRIVAL STRUCTURE -- ANGLE VS. RANGE



FAST SAMPLE [illegible] PROFILE IN MTRS AND MTRS/SEC WITH TWO POINT LAYER.   10.51.09   09/27/76

SOURCE DEPTH = [illegible] FT, RECEIVER DEPTH = [illegible] FT

TRANSMISSION LOSS (IN DB RE 1 YD)

RANGE (N MI)	[illegible] HZ, [illegible]	[illegible] HZ, [illegible]
1.[illegible]	[illegible]	[illegible]
2.[illegible]	[illegible]	[illegible]
3.[illegible]	[illegible]	[illegible]
4.[illegible]	[illegible]	[illegible]
5.[illegible]	[illegible]	[illegible]
6.[illegible]	[illegible]	[illegible]
7.[illegible]	[illegible]	[illegible]
8.[illegible]	[illegible]	[illegible]
9.[illegible]	[illegible]	[illegible]
10.[illegible]	[illegible]	[illegible]
11.[illegible]	[illegible]	[illegible]
12.[illegible]	[illegible]	[illegible]
13.[illegible]	[illegible]	[illegible]
14.[illegible]	[illegible]	[illegible]
15.[illegible]	[illegible]	[illegible]
16.[illegible]	[illegible]	[illegible]
17.[illegible]	[illegible]	[illegible]
18.[illegible]	[illegible]	[illegible]
19.[illegible]	[illegible]	[illegible]
20.[illegible]	[illegible]	[illegible]
21.[illegible]	[illegible]	[illegible]
22.[illegible]	[illegible]	[illegible]
23.[illegible]	[illegible]	[illegible]
24.[illegible]	[illegible]	[illegible]
25.[illegible]	[illegible]	[illegible]
26.[illegible]	[illegible]	[illegible]
27.[illegible]	[illegible]	[illegible]
28.[illegible]	[illegible]	[illegible]
29.[illegible]	[illegible]	[illegible]
30.[illegible]	[illegible]	[illegible]
31.[illegible]	[illegible]	[illegible]
32.[illegible]	[illegible]	[illegible]
33.[illegible]	[illegible]	[illegible]
34.[illegible]	[illegible]	[illegible]
35.[illegible]	[illegible]	[illegible]
36.[illegible]	[illegible]	[illegible]
37.[illegible]	[illegible]	[illegible]
38.[illegible]	[illegible]	[illegible]
39.[illegible]	[illegible]	[illegible]
40.[illegible]	[illegible]	[illegible]
41.[illegible]	[illegible]	[illegible]
42.[illegible]	[illegible]	[illegible]
43.[illegible]	[illegible]	[illegible]
44.[illegible]	[illegible]	[illegible]
45.[illegible]	[illegible]	[illegible]
46.[illegible]	[illegible]	[illegible]
47.[illegible]	[illegible]	[illegible]
48.[illegible]	[illegible]	[illegible]
49.[illegible]	[illegible]	[illegible]
50.[illegible]	[illegible]	[illegible]
51.[illegible]	[illegible]	[illegible]
52.[illegible]	[illegible]	[illegible]
53.[illegible]	[illegible]	[illegible]
54.[illegible]	[illegible]	[illegible]
55.[illegible]	[illegible]	[illegible]
56.[illegible]	[illegible]	[illegible]
57.[illegible]	[illegible]	[illegible]

FAST SAMPLE RUN NO. 2 -- PROFILE IN MTRS AND MTRS/SEC WITH TWO POINT LAYER. 18.56.59 09/27/76

SOURCE DEPTH = [illegible] FT. RECEIVER DEPTH = [illegible] FT

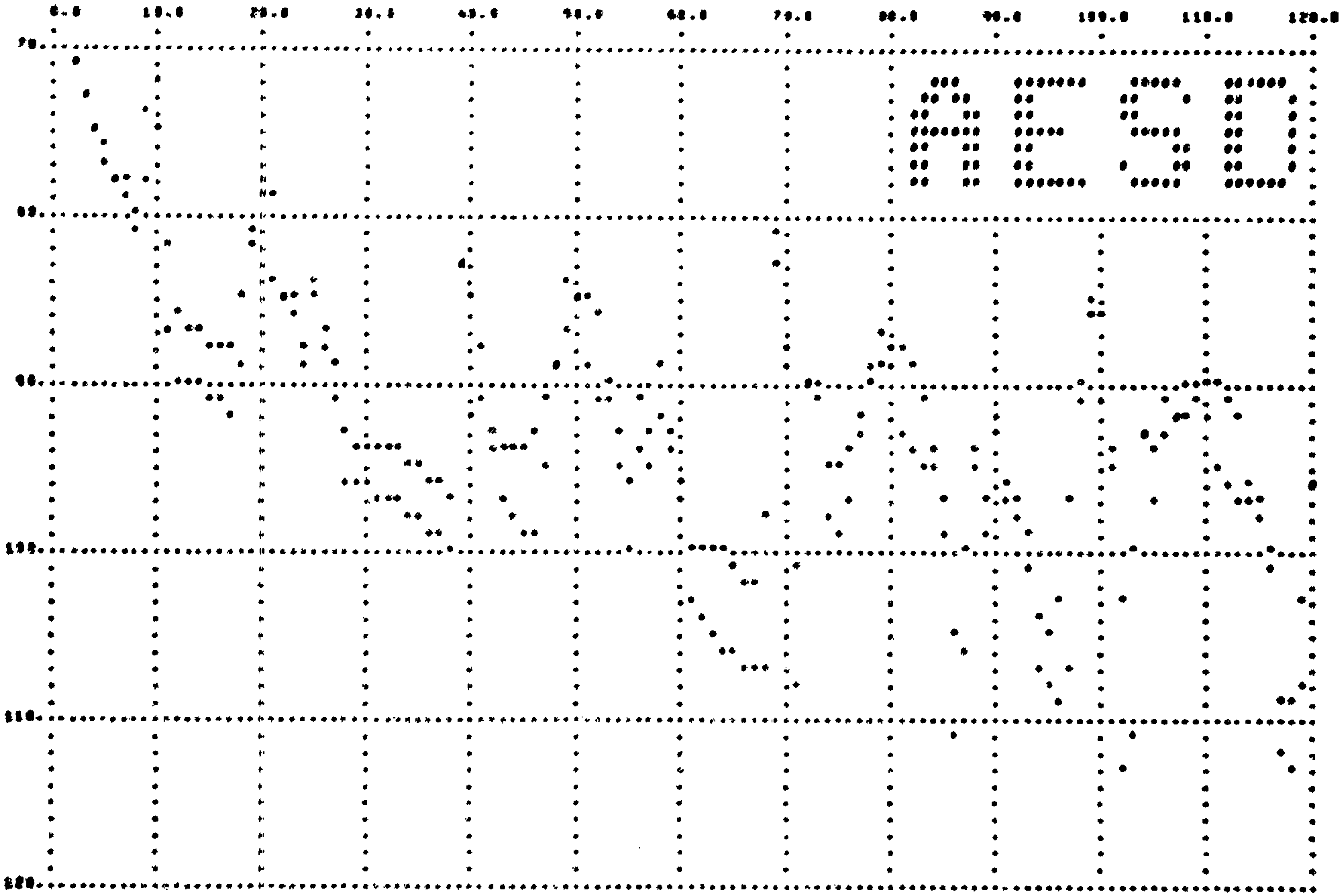
TRANSMISSION LOSS [illegible]

RANGE IN KM	100 HZ. SCOM	33. HZ. SCOM
1.[illegible]	69.9	68.5
2.[illegible]	75.7	79.6
3.[illegible]	73.6	73.1
4.[illegible]	74.9	75.3
5.[illegible]	74.3	76.6
6.[illegible]	77.9	77.9
7.[illegible]	78.2	78.9
8.[illegible]	86.1	80.9
9.[illegible]	74.1	70.8
10.[illegible]	76.9	72.8
11.[illegible]	91.4	86.9
12.[illegible]	87.1	86.6
13.[illegible]	87.1	90.6
14.[illegible]	87.9	91.6
15.[illegible]	87.1	90.7
16.[illegible]	88.8	91.1
17.[illegible]	87.6	91.7
18.[illegible]	85.6	89.3
19.[illegible]	91.4	88.7
20.[illegible]	79.9	70.1
21.[illegible]	79.3	81.7
22.[illegible]	94.9	95.2
23.[illegible]	85.3	86.1
24.[illegible]	87.7	89.1
25.[illegible]	85.1	81.7
26.[illegible]	94.0	87.6
27.[illegible]	89.6	90.0
28.[illegible]	92.4	97.0
29.[illegible]	93.5	94.3
30.[illegible]	94.8	94.3
31.[illegible]	[illegible]	96.7
32.[illegible]	93.0	97.1
33.[illegible]	96.8	97.6
34.[illegible]	96.7	97.9
35.[illegible]	99.4	96.5
36.[illegible]	99.7	99.8
37.[illegible]	94.9	98.6
38.[illegible]	94.6	100.7
39.[illegible]	92.6	93.3
40.[illegible]	96.7	97.1
41.[illegible]	99.3	97.3
42.[illegible]	92.8	94.6
43.[illegible]	97.0	99.6
44.[illegible]	96.7	97.5
45.[illegible]	94.3	99.8
46.[illegible]	97.9	99.2
47.[illegible]	91.6	99.4
48.[illegible]	89.6	98.7
49.[illegible]	89.5	84.2
50.[illegible]	85.1	86.0
51.[illegible]	84.8	89.5
52.[illegible]	84.7	88.6
53.[illegible]	92.8	93.5
54.[illegible]	93.1	90.0
55.[illegible]	98.9	98.9
56.[illegible]	98.5	93.7
57.[illegible]	93.4	[illegible]

FAST SAMPLE RUN NO. 2 -- PROFILE IN NERS AND HYDS/KIC WITH TWO POINT LAYER. 10.51.46 09/27/76

SOURCE DEPTH = 531.2 FT, RECEIVER DEPTH = 18032.0 FT

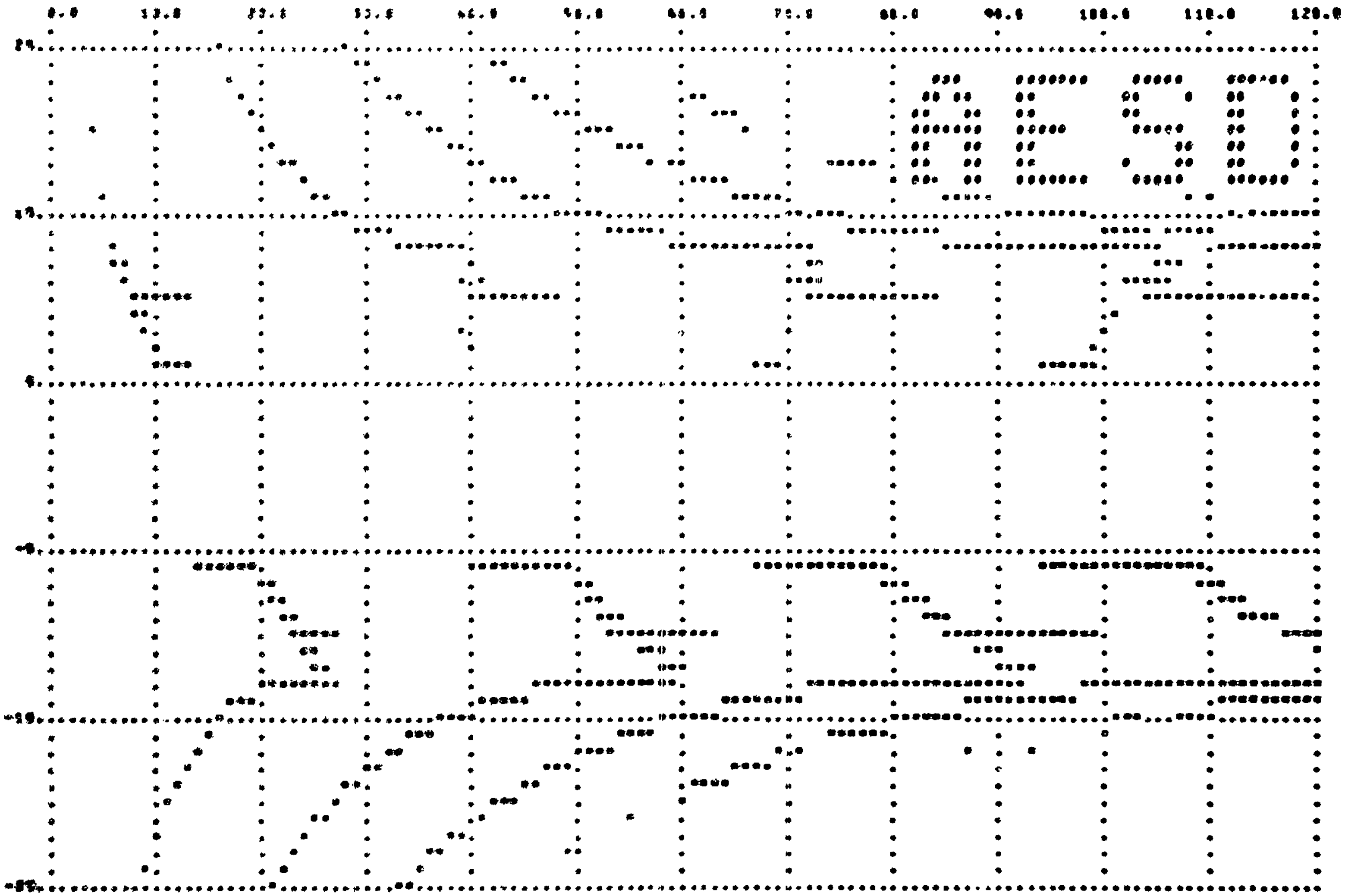
LEGEND-- 133 HZ. SCOM = * 338 HZ. SCOM = +



FACT SAMPLE RUN NO. 2 -- PROFILE IN MTRS AND MTRS/SEC WITH TWO POINT LAYER. 10.51.09 09/27/76

SOURCE DEPTH = 984.0 FT. RECEIVER DEPTH = 10003.? FT

ARRIVAL STRUCTURE -- ANGLE VS. RANGE



[illegible] PROFILE TO [illegible] WITH TWO POINT LAYER. 16.51.09 09/27/76

SOURCE DEPTH = [illegible] FT. RECEIVER DEPTH = [illegible] FT

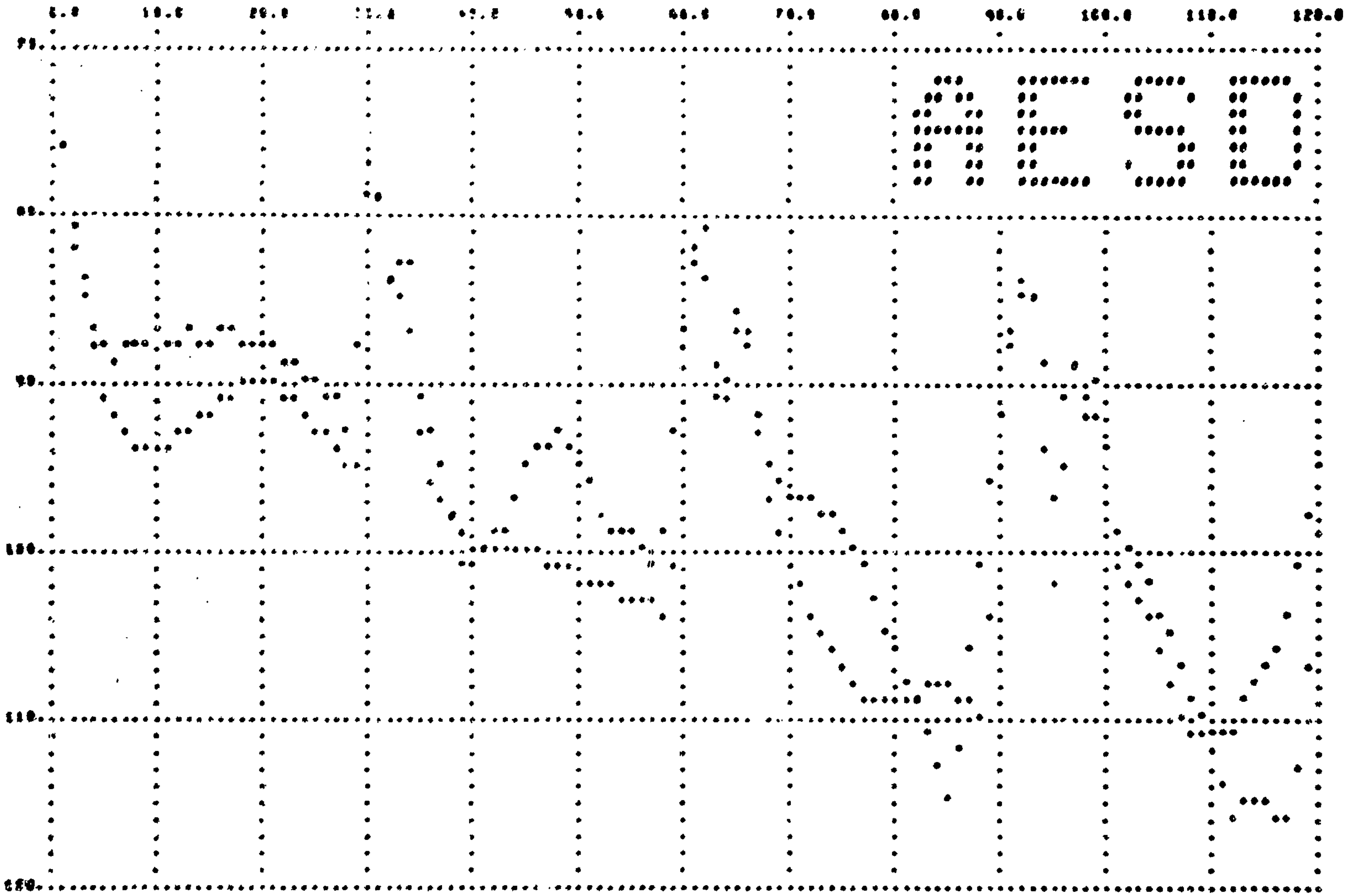
TRANSMISSION LOSS (DB RE 1 YD)

RANGE (N MI)	[illegible] FT, [illegible]	[illegible] FT, [illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

FAST SAMPLE RUN NO. 2 -- PROFILE IN MTRS AND MTRS/SEC WITH TWO POINT LAYER.   10.51.14   09/27/76

SOURCE DEPTH = 984.0 FT. RECEIVER DEPTH = 300.0 FT

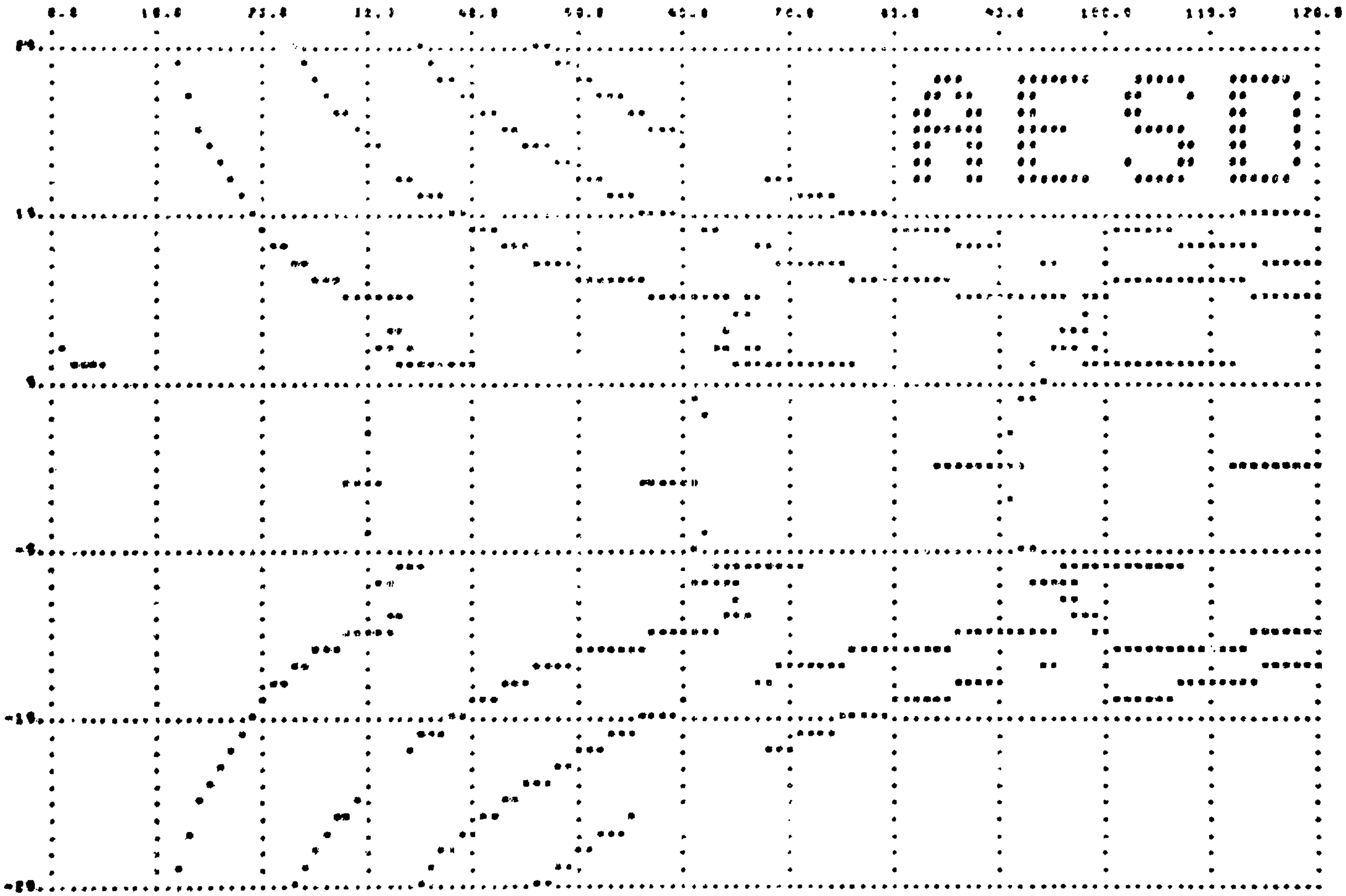
LEGEND-- [illegible] HZ. SCOM = *   [illegible] HZ. SCOM = *



FAST SAMPLE RUN NO. 2 -- PROFILE IN MTRS AND MTRS/SEC WITH TWO POINT LAYER.   15.51.19   09/27/76

SOURCE DEPTH =   985.0 FT, RECEIVER DEPTH =   328.0 FT

ARRIVAL STRUCTURE -- ANGLE VS. RANGE



P-CT SAMPLE RUN NO. 1 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS.

-16 1 2 1

0.00000	12.36000	35.11300	0.00000	1498.64511	4917.47883
10.00000	12.60000	35.12300	32.80840	1496.06219	4914.98221
20.00000	11.76000	35.13000	65.61680	1497.06402	4911.62737
38.00000	11.11000	35.15300	124.67192	1495.17917	4905.44349
77.00000	9.56000	35.31000	252.62467	1490.44841	4889.69635
125.00000	8.98000	35.27000	413.10499	1489.82675	4885.25836
153.00000	8.71000	35.25000	501.96850	1488.44846	4883.36154
229.00000	8.26000	35.21000	751.31234	1487.71388	4880.95879
379.00000	7.69000	35.15000	1243.43832	1488.91291	4884.39497
528.00000	7.42000	35.14000	1732.28346	1489.57955	4886.54976
614.00000	7.12000	35.11000	2014.43570	1490.75384	4887.63398
814.00000	5.87000	35.04000	2670.60367	1487.41176	4881.27217
1021.00000	4.95300	34.96000	3349.73753	1485.95822	4875.19102
1200.00000	4.20300	34.92000	3937.00787	1487.76817	4881.12917
1400.00000	3.99000	34.89000	4593.17585	1489.86432	4888.08631
1551.00000	3.76000	34.89000	5088.59260	1491.43559	4893.16138

120 2.00

90.02 196.00

FACT SAMPLE RUN NO. 1 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS. 10.51.19 09/27/76

SOURCE DEPTH = 60.0 FT. RECEIVER DEPTH = 630.0 FT

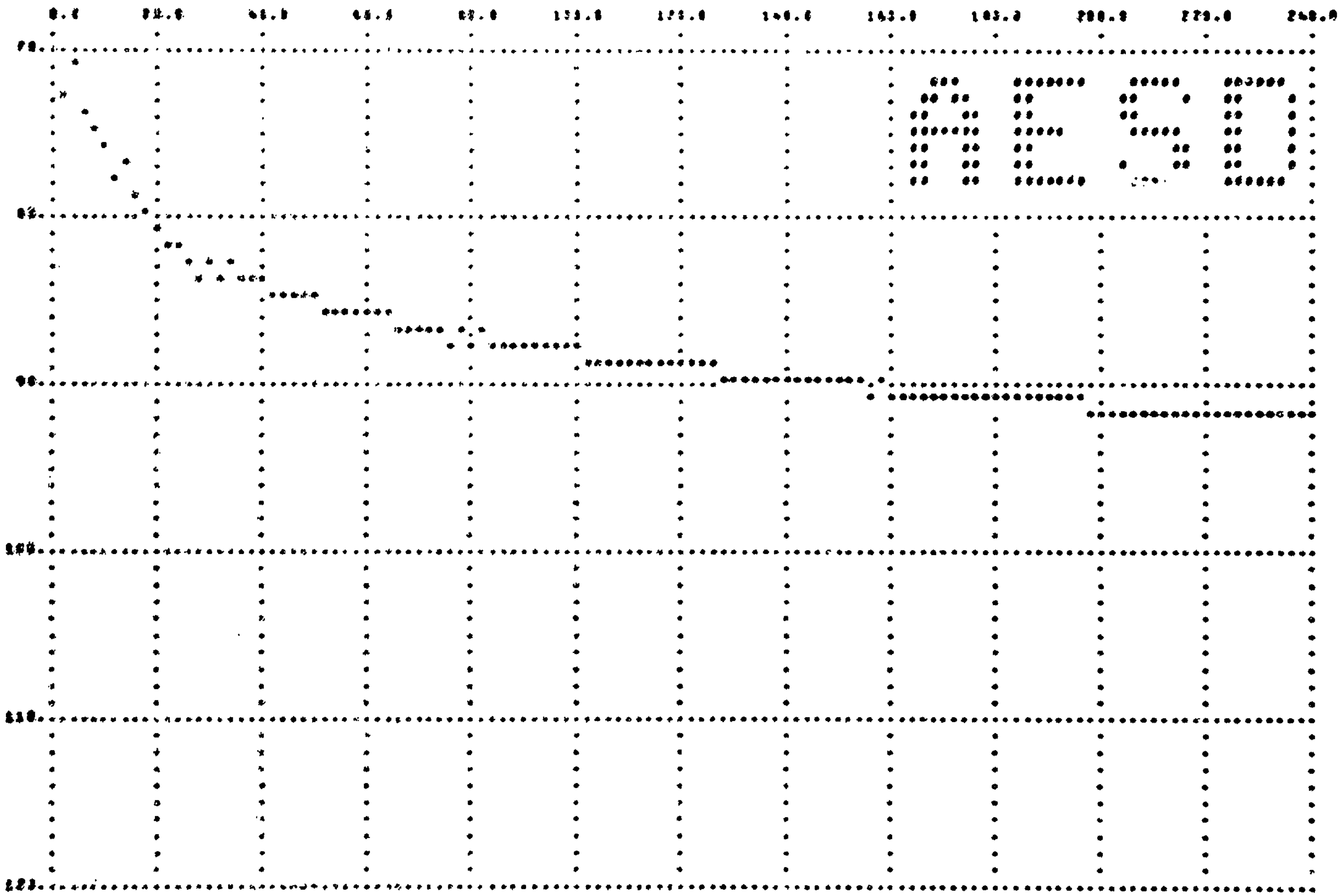
TRANSMISSION LOSS (DB RE 1 YD)

RANGE (N MI)	50 HZ, SCOM	150 HZ, SCOM
2.00	73.1	71.1
4.00	73.5	72.4
6.00	73.5	74.9
8.00	75.6	75.6
10.00	77.6	76.7
12.00	77.7	77.6
14.00	77.6	74.1
16.00	79.7	[illegible]
18.00	78.7	80.2
20.00	80.7	81.1
22.00	81.7	81.5
24.00	82.6	81.5
26.00	87.5	81.4
28.00	81.7	82.3
30.00	82.9	87.6
32.00	81.8	82.8
34.00	59.2	82.4
36.00	[illegible]	83.7
38.00	34.7	83.5
40.00	[illegible]	83.8
42.00	85.1	86.2
44.00	86.7	84.2
46.00	89.3	84.4
48.00	85.3	84.6
50.00	35.6	84.7
52.00	[illegible]	79.3
54.00	84.7	85.1
56.00	87.2	85.3
58.00	85.9	89.4
60.00	85.4	85.6
62.00	86.6	85.7
64.00	84.6	85.8
66.00	86.9	86.8
68.00	84.8	86.1
70.00	87.1	86.3
72.00	84.8	86.6
74.00	87.2	85.6
76.00	87.8	86.7
78.00	87.3	86.7
80.00	87.6	86.9
82.00	87.6	86.9
84.00	87.8	67.1
86.00	87.9	87.2
88.00	87.9	87.3
90.00	88.3	87.5
92.00	85.8	87.5
94.00	88.3	87.6
96.00	88.1	87.6
98.00	88.6	87.8
100.00	86.5	87.9
102.00	88.5	88.6
104.00	88.8	88.2
106.00	88.7	88.?
108.00	90.9	88.?
110.00	90.9	68.3
112.00	90.8	60.4
114.00	89.2	88.5

FACT SAMPLE RUN NO. 3 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS. 10.51.32 09/27/76

SOURCE DEPTH = 60.0 FT. RECEIVER DEPTH = 633.3 FT

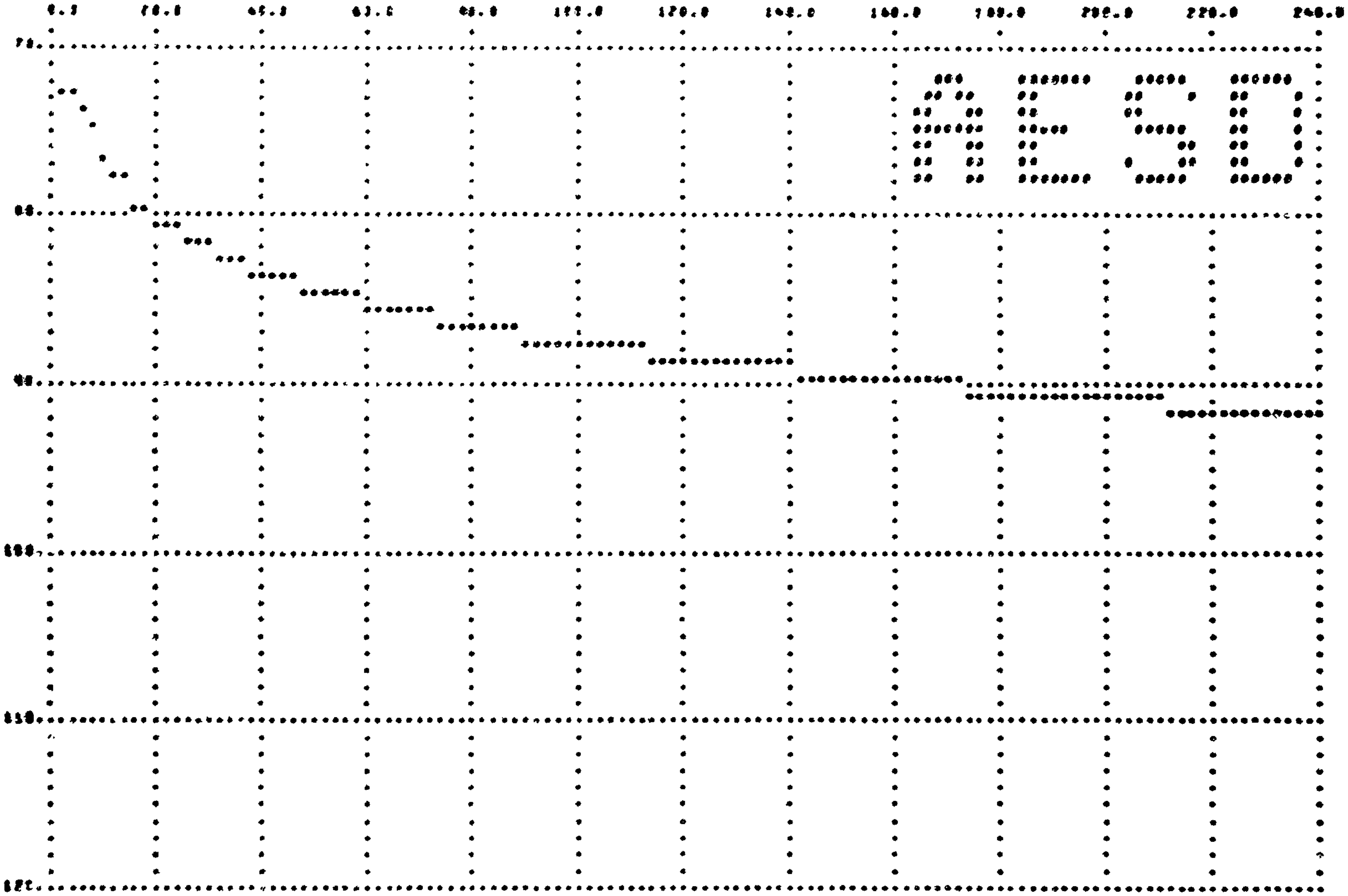
LEGEND-- 57 HZ. TCRH = *



FACT SAMPLE RUN NO. 3 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS.   10.51.33   09/27/76

SOURCE DEPTH = 61.0 FT. RECEIVER DEPTH = 600.0 FT

LEGEND-- 153 HZ. SCOM = *



FAST SAMPLE RUN NO. [illegible] PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS. 10.51.32 09/27/76

SOURCE DEPTH = [illegible] FT. RECEIVER DEPTH = [illegible] FT

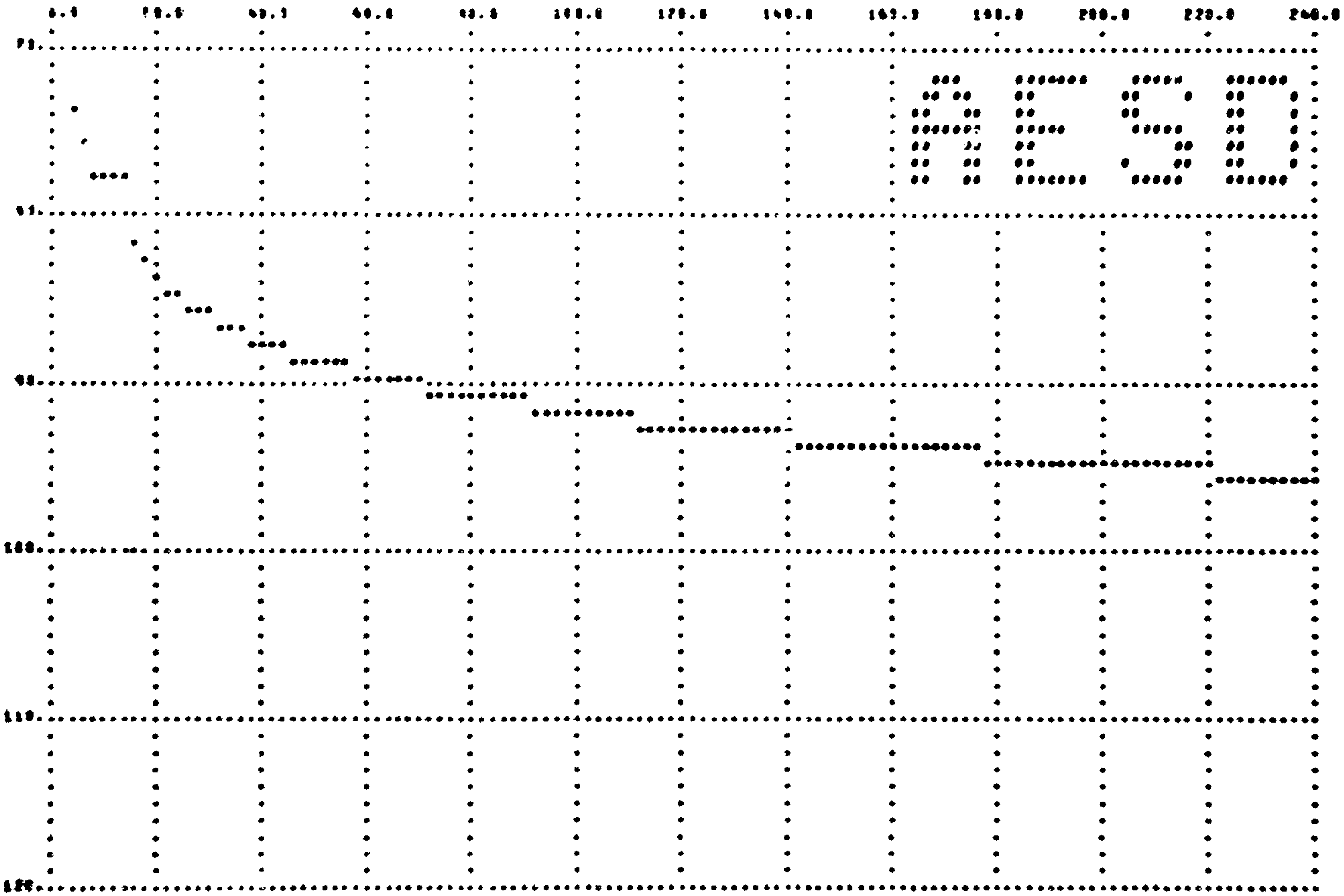
TRANSMISSION LOSS (DB RE 1 YD)

RANGE IN KM.	[illegible] HZ. SCOM	[illegible] HZ. SCOM
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

FACT SAMPLE RUN NO. 3 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS. 10.51.30 09/27/76

SOURCE DEPTH = 300.0 FT. RECEIVER DEPTH = 6300.0 FT

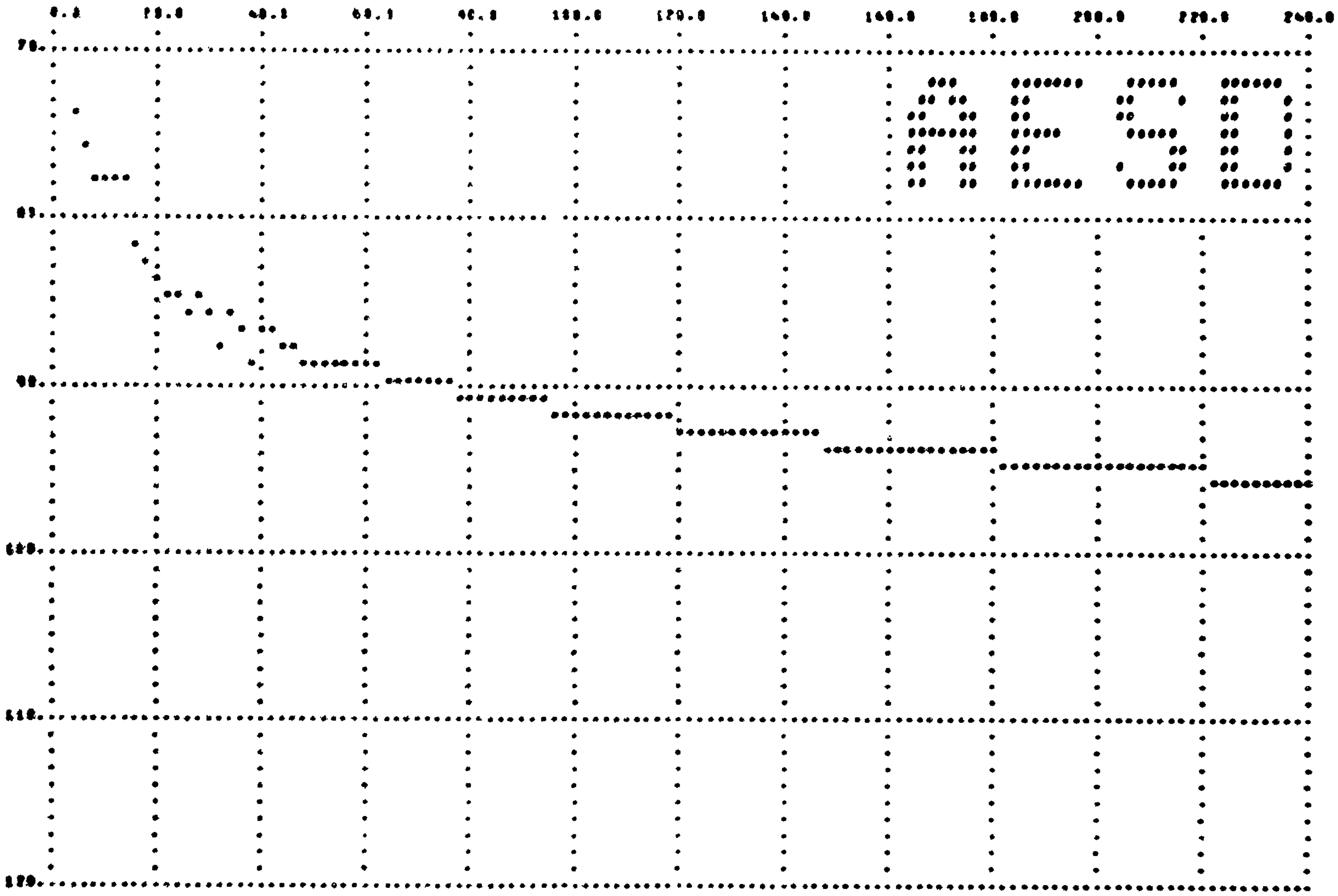
LEGEND-- 53 HZ. SCOM = *



FAST SAMPLE RUN NO. 1 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS. 10.51.38 09/27/76

SOURCE DEPTH = 300.0 FT. RECEIVER DEPTH = 6500.0 FT

LEGEND-- 133 HZ. SCOM = *



THE FOLLOWING PAGES CONTAIN A COMPLETE FORTRAN COMPILATION (ON THE CDC 6700) OF ALL ROUTINES WHICH COMPRISE THE AESD FACT PACKAGE.

THE AESD DESIGNATION FOR THIS PARTICULAR VERSION IS--

FACTMKCPL9C

ALL INQUIRIES REGARDING THE CODE SHOULD REFER TO THIS DESIGNATION, AND, IF APPLICABLE, THE INDIVIDUAL CARD IDENTIFIERS WHICH APPEAR AT THE RIGHT ON EACH LINE OF CODE.

MACHINE-READABLE SOURCE CODE, EITHER IN CARDS, OR IN SEVEN- OR NINE-TRACK MAGNETIC TAPE FORMAT, IS AVAILABLE UPON WRITTEN REQUEST TO AESD.

IT IS EXPECTED THAT UPDATED VERSIONS OF FACT WILL CONTINUE TO BE DEVELOPED BY AESD. ORGANIZATIONS WHICH HAVE RECEIVED MACHINE-READABLE DISTRIBUTIONS WILL AUTOMATICALLY BE NOTIFIED AS TO THE AVAILABILITY OF THESE UPDATED VERSIONS AS THEY APPEAR.

```
      PROGRAM TLOSS(INPUT, OUTPUT, TAPE8, TAPE5=INPUT, TAPE6=OUTPUT)    TLOSS   2
C                                                                       TLOSS   3
C                                                                       TLOSS   4
      DIMENSION TITLE(8), Z(50), C(50), F(6), IF(6), IC(6), JC(6),      TLOSS   5
     *          IS(6), TL(250,6)                                        TLOSS   6
C                                                                       TLOSS   7
      DATA IS /1H*, 1H+, 1HX, 1HO, 1H-, 1H$/                            TLOSS   8
C                                                                       TLOSS   9
C                                                                       TLOSS  10
C        PROGRAM TLOSS IS THE INPUT/OUTPUT DRIVER FOR THE FACTTL        TLOSS  11
C        TRANSMISSION LOSS SUBROUTINE.                                  TLOSS  12
C        TLOSS READS INPUT DATA, CALLS FACTTL, AND PRINTS, OR PLOTS,    TLOSS  13
C        OR BOTH PRINTS AND PLOTS THE RESULTS.                          TLOSS  14
C        CYCLES ON SOURCE/RECEIVER DEPTH COMBINATIONS                   TLOSS  15
C        AND/OR ON COMPLETE INPUT DECKS.                                TLOSS  16
C        ARRAY IS (ABOVE) CONTAINS THE SYMBOLS FOR PLOTTING.            TLOSS  17
C                                                                       TLOSS  18
C                                                                       TLOSS  19
C                                                                       TLOSS  20
C        READ AND PRINT FIRST CARD -- 80 COLUMNS OF TITLE INFORMATION   TLOSS  21
C                                                                       TLOSS  22
    5 READ (5,10)  (TITLE(I), I = 1,8)                                  TLOSS  23
   10 FORMAT (8A10)                                                     TLOSS  24
C                                                                       TLOSS  25
      IF (EOF(5).NE.0)  STOP                                            TLOSS  26
C                                                                       TLOSS  27
      WRITE (6,15)  (TITLE(I), I = 1,8)                                 TLOSS  28
   15 FORMAT (///,1H1,8A10,/)                                           TLOSS  29
C                                                                       TLOSS  30
C                                                                       TLOSS  31
C        READ AND PRINT SECOND CARD                                     TLOSS  32
C                                                                       TLOSS  33
C              N = NO. OF POINTS IN PROFILE                             TLOSS  34
C                = + FOR VELOCITY VERSUS DEPTH                          TLOSS  35
C                = - FOR TEMP. AND SALINITY VERSUS DEPTH                TLOSS  36
C                                                                       TLOSS  37
C             IL = INDEX OF LAYER DEPTH IN PROFILE                      TLOSS  38
C                = 0,1 FOR NO LAYER PRESENT                             TLOSS  39
C                = N FOR HALF CHANNEL MODEL                             TLOSS  40
C                                                                       TLOSS  41
C             IB = BOTTOM LOSS INDEX (1-5)                              TLOSS  42
C                                                                       TLOSS  43
C             IW = WAVE HEIGHT IN FEET                                  TLOSS  44
C                                                                       TLOSS  45
C            IPL = PLOT/PRINT FLAG                                      TLOSS  46
C                = 0            PRINT ONLY                              TLOSS  47
C                = +1, -1       PLOT ONLY                               TLOSS  48
C                = +2, -2       PRINT AND PLOT                          TLOSS  49
C                = +            SEPARATE PLOTS FOR EACH FREQUENCY       TLOSS  50
C                = -            ONE PLOT FOR ALL FREQUENCIES            TLOSS  51
C                                                                       TLOSS  52
C            IAR = 0            DO NOT COMPUTE ARRIVAL STRUCTURE        TLOSS  53
C            IAR = 1            COMPUTE AND PLOT ARRIVAL STRUCTURE      TLOSS  54
C                                                                       TLOSS  55
C                                                                       TLOSS  56
```

```
      READ (5,20)  N, IL, IB, IM, IPL, IAR
   20 FORMAT (6I5)
C
      WRITE (6,25)  N, IL, IB, IM
   25 FORMAT (1H , 4I5, /)
C
      NN = IM
      IP = 2
      IF (IAR.NE.0)  IAR = 9
C
C
C        CALL RDPROF TO READ PROFILE CARDS, CONVERT TO
C        ENGLISH UNITS IF REQUIRED, AND PRINT OUT RESULTS.
C
      CALL RDPROF(N, Z, C)
C
C
C        READ AND PRINT RANGE CARD
C
C                 NR = NO. OF RANGE POINTS (.LE. 250)
C              DRNMI = INCREMENTAL RANGE IN N.MI.
C
      READ (5,40)  NR, DRNMI
   40 FORMAT (I5, 5X, F12.2)
C
      WRITE (6,45)  NR, DRNMI
   45 FORMAT (///, 1H , I5, 5X, F10.2, /)
C
      DR = DRNMI*6076.1
C
C
C        READ FREQUENCY CARD, COUNT FREQUENCIES,
C        AND PRINT FREQUENCIES (IN HERTZ)
C
      READ (5,50)  (F(I),  I = 1,6)
   50 FORMAT (6F10.2)
C
      DO 51  I = 1,6
      IF (F(I).EQ.0.)  GO TO 52
      IF(I) = F(I) + .5
      NF = I
   51 CONTINUE
C
   52 CONTINUE
C
      WRITE (6,55)  (F(I),  I = 1,NF)
   55 FORMAT (1H , 6F10.2, /)
C
   60 CONTINUE
C
C
C        READ DEPTHS AND COHERENCY FLAGS
C
C                  S = SOURCE DEPTH IN FEET (OR END OF S-R CARDS FLAG)
C                  R = RECEIVER DEPTH IN FEET
```

```
C            JC(I) = COHERENCY FOR I-TH FREQUENCY
C                  = 0 FOR SEMI-COHERENCY
C                  = 1 FOR INCOHERENT
C                  = 2 FOR FULLY COHERENT
C
      READ (5,65)  S, R, (JC(I),  I = 1,NF)
   65 FORMAT (2F10.2, 41I)
C
      IF (EOF(5).NE.0)  STOP
C
C        IF SOURCE DEPTH IS FLAGGED TO INDICATE END OF S/R CARDS,
C        GO TO READ NEW RUN DATA BEGINNING WITH TITLE CARD
C
      IF (ABS(S).GE.11111.)  GO TO 5
C
      IF (S.LT.0.)  S = Z(N)
      IF (R.LT.0.)  R = Z(N)
C
C
C        CONVERT COHERENCY FLAGS TO INTERNAL VALUES
C
      DO 69  I = 1,NF
      IF (JC(I).EQ.0)  IC(I) = 2
      IF (JC(I).EQ.1)  IC(I) = 0
      IF (JC(I).EQ.2)  IC(I) = 1
   69 CONTINUE
C
C
C        PRINT HEADING FOR PRINTED OUTPUT (IF FLAGGED)
C
      IF (IABS(IPL).NE.1)  CALL TLHEAD(TITLE, S, R, IF, JC, IT, NF, 0)
C
C        CALL FACTIL SUBROUTINE FOR TRANSMISSION LOSSES
C        AND (IF FLAGGED) ARRIVAL STRUCTURE
C
C
      IF (IAR.NE.0)  REWIND IAR
C
      CALL FACTIL(S, R, F, IC, NM, IB, N, IL, Z, C, NR, DR, IAR, TL, IP)
C
      IF (IAR.NE.0)  ENDFILE IAR
      IF (IAR.NE.0)  REWIND IAR
C
C
C        IF CASE WAS ABORTED, GO TO READ NEXT S,R CARD
C
      IF (TL(1,1).EQ.0.0)  GO TO 60
C
C
      IF (IABS(IPL).EQ.1)  GO TO 131
C
C        PRINT LOSSES VS. RANGE (IF FLAGGED)
C
      RANGE = C.
C
```

```
      DO 101  I = 1,NR
      RANGE = RANGE + DRNMI
      WRITE (6,98)  RANGE, (TL(I,J),  J = 1,NF)
   98 FORMAT (1H , 6X, F7.2, 4X, 6(5X, F5.1, 5X))
  101 CONTINUE
C
C        SKIP PLOTTING (IF NOT FLAGGED)
C
      IF (IPL.EQ.0)  GO TO 300
C
C
  111 CONTINUE
      MINDB = FS
      IF (IPL.LT.3)  GO TO 200
C
C        CALL TLHEAD AND PLOTTL TO PLOT LOSS VS. RANGE
C        FOR EACH FREQUENCY IN TURN
C
      DO 110  L = 1,NF
      CALL TLHEAD(TITLE, S, R, IF(L), JC(L), IR, 1, 1)
      CALL PLOTTL(NR, DRNMI, 1, IR(L), MINDB, TL(1,L))
  110 CONTINUE
C
      GO TO 300
C
C
C        CALL TLHEAD AND PLOTTL TO PLOT LOSS VS. RANGE
C        FOR ALL FREQUENCIES AT ONCE
C
  200 CALL TLHEAD(TITLE, S, R, IF, JC, IR, NF, 1)
      CALL PLOTTL(NR, DRNMI, NF, IR, MINDB, TL)
C
C
  300 CONTINUE
C
      IF (IAA.EQ.0)  GO TO 60
C
C        PLOT ARRIVAL STRUCTURE (IF FLAGGED)
C
C        FIRST CLEAR TL ARRAY TO -100. DEGREES IN PREPARATION TO
C        USING IT TO STORE ANGLES VS. RANGE
C
      DO 315  I = 1,250
      DO 310 J = 1,6
      TL(I,J) = 100.0
C
  310 CONTINUE
C
C
  320 CONTINUE
C
C        READ ARRIVAL RANGE, ANGLE
C
      READ (IAR,330)  RNMI, THETAO, D1, D2, D3, D4, D5, D6
  330 FORMAT (1X, F6.1, 2X, F7.1, 6(2X, F5.1))
```

```
C
      IF (ICW(ITAR).NE.0)  GO TO 369
C
C        COMPUTE RANGE INDEX I FOR THIS RANGE
C
      I = RNMI/DRNMI + .9999
C
C        ROUND ANGLE TO NEAREST INTEGER (DISREGARD IF .GT. 25 DEGREES)
C
      ITH = ABS(THETAD) + .5
      IF (ITH.GT.25)  GO TO 323
      THETAI = ITH
      THETAI = SIGN(THETAI,THETAD)
C
C        PUT ANGLE IN TL AT INDEX I IF NOT ALREADY THERE
C
      DO 349 J = 1,6
      IF (TL(I,J).EQ.THETAI)  GO TO 320
      IF (TL(I,J).NE.100.0)  GO TO 349
      TL(I,J) = THETAI
      GO TO 320
  349 CONTINUE
C
      GO TO 320
C
C
  369 CONTINUE
C
C
C        CALL TMLEAD AND PLOTLL TO PLOT ARRIVAL STRUCTURE
C
      MINANG = -25
      CALL TMLEAD(TITLE, 5, 0, 0, 1, 0, 0, 2)
      CALL PLOTLL(NR, DRNMI, 6, 0, MINANG, TL)
      GO TO 83
C
      END
```

DISTRIBUTION LIST

[illegible] Corporation

Andrulis Research Corp.

Antisubmarine Warfare Systems Project

Australian Naval Scientific Service

Bell Telephone Laboratory

Bunker-Ramo Corporation

Central Intelligence Agency

Chesapeake Instruments Corp.

General Electric Company

General Dynamics

International Business Machines

Interstate Electronics Corp.

Johns Hopkins University

[illegible] Systems, Inc.

Lockheed Missiles & Space Company, Inc.

[illegible] & Associates, Inc.

Marine Physical Laboratory

[illegible] Research, Inc.

NATO SACLANT Antisubmarine Warfare Research Centre

Naval Air Development Center

Naval Air Systems Command

Naval [illegible] Center

Naval Electronic Systems Command

Naval Intelligence Support Center

Naval Oceanographic Office

Naval Research Laboratory

Naval Sea Systems Command

Naval Ship Research and Development Center

Naval Surface Weapons Center

Naval Undersea Center

Naval Underwater Systems Center

Naval Training Equipment Center

Pennsylvania State Univ.

[illegible] Associates, Inc.

Rockwell International Corporation

Sanders Associates

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
875 NORTH RANDOLPH STREET
SUITE 1425
ARLINGTON VA 22203-1995

IN REPLY REFER TO:

5510/1
Ser 321OA/011/06
31 Jan 06

MEMORANDUM FOR DISTRIBUTION LIST

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

Ref: (a) SECNAVINST 5510.36

Encl: (1) List of DECLASSIFIED LRAPP Documents

1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.

2. The LRAPP documents listed in enclosure (1) have been downgraded to UNCLASSIFIED and have been approved for public release. These documents should be remarked as follows:

   Classification changed to UNCLASSIFIED by authority of the Chief of Naval Operations (N772) letter N772A/6U875630, 20 January 2006.

   DISTRIBUTION STATEMENT A: Approved for Public Release; Distribution is unlimited.

3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

BRIAN LINK
By direction

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

DISTRIBUTION LIST:

NAVOCEANO (Code N121LC – Jaime Ratliff)
NRL Washington (Code 5596.3 – Mary Templeman)
PEO LMW Det San Diego (PMS 181)
DTIC-OCQ (Larry Downing)
ARL, U of Texas
Blue Sea Corporation (Dr.Roy Gaul)
ONR 32B (CAPT Paul Stewart)
ONR 321OA (Dr. Ellen Livingston)
APL, U of Washington
APL, Johns Hopkins University
ARL, Penn State University
MPL of Scripps Institution of Oceanography
WHOI
NAVSEA
NAVAIR
NUWC
SAIC

Declassified LRAPP Documents

Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
Unavailable	Beam, J. P., et al.	LONG-RANGE ACOUSTIC PROPAGATION LOSS MEASUREMENTS OF PROJECT TRANSLANT I IN THE ATLANTIC OCEAN EAST OF BERMUDA	Naval Underwater Systems Center	740612	ADC001521	U
Unavailable	Cornyn, J. J., et al.	AMBIENT-NOISE PREDICTION. VOLUME 2. MODEL EVALUATION WITH IOMEDEX DATA	Naval Research Laboratory	740701	AD0530983	U
Unavailable	Unavailable	COHERENCE OF HARMONICALLY RELATED CW SIGNALS	Naval Underwater Systems Center	740722	ADB181912	U
Unavailable	Banchero, L. A., et al.	IOMEDEX SOUND VELOCITY ANALYSIS AND ENVIRONMENTAL DATA SUMMARY	Naval Oceanographic Office	740801	ADC000419	U
3810	Unavailable	CONSTRUCTION AND CALIBRATION OF USRD TYPE F58 VIBROSEIS MONITORING HYDROPHONES SERIALS 1 THROUGH 7	Naval Research Laboratory	741002	ND	U
ARL-TM-73-11; ARL-TM-73-12	Ellis, G. E., et al.	ARL PRELIMINARY DATA ANALYSIS FROM ACODAC SYSTEM; ANALYSIS OF THE BLAKE TEST ACODAC DATA	University of Texas, Applied Research Laboratories	741015	ADA001738; ND	U
Unavailable	Mitchell, S. K., et al.	QUALITY CONTROL ANALYSIS OF SUS PROCESSING FROM ACODAC DATA	University of Texas, Applied Research Laboratories	741015	ADB000283	U
Unavailable	Unavailable	MEDEX PROCESSING SYSTEM. VOLUME II. SOFTWARE	Bunker-Ramo Corp. Electronic Systems Division	741021	ADB000363	U
Unavailable	Spofford, C. W.	FACT MODEL. VOLUME I	Maury Center for Ocean Science	741101	ADA078581	U
Unavailable	Bucca, P. J., et al.	SOUND VELOCITY STRUCTURE OF THE LABRADOR SEA, IRMINGER SEA, AND BAFFIN BAY DURING THE NORLANT-72 EXERCISE	Naval Oceanographic Office	741101	ADC000461	U
Unavailable	Anderson, V. C.	VERTICAL DIRECTIONALITY OF NOISE AND SIGNAL TRANSMISSIONS DURING OPERATION CHURCH ANCHOR	Scripps Institution of Oceanography Marine Physical Laboratory	741115	ADA011110	U
Unavailable	Baker, C. L., et al.	FACT MODEL. VOLUME II	Office of Naval Research	741201	ADA078539	U
ARL-TR-74-53	Anderson, A. L.	CHURCH ANCHOR EXPLOSIVE SOURCE (SUS) PROPAGATION MEASUREMENTS (U)	University of Texas, Applied Research Laboratories	741201	ADC002497; ND	U
MCR106	Cherkis, N. Z., et al.	THE NEAT 2 EXPERIMENT VOL 1 (U)	Maury Center for Ocean Science	741201	NS; ND	U
MCR107	Cherkis, N. Z., et al.	THE NEAT 2 EXPERIMENT VOL 2 - APPENDICES (U)	Maury Center for Ocean Science	741201	NS; ND	U
Unavailable	Mahler, J., et al.	INTERIM SHIPPING DISTRIBUTION	Tetra, Tech, BB&N, & PSI	741217	ND	U
75-9M7-VERAY-R1	Jones, C. H.	LRAPP VERTICAL ARRAY- PHASE IV	Westinghouse Electric Corp.	750113	ADA008427; ND	U
AESD-TN-75-01	Spofford, C. W.	ACOUSTIC AREA ASSESSMENT	Office of Naval Research	750201	ADA090109; ND	U